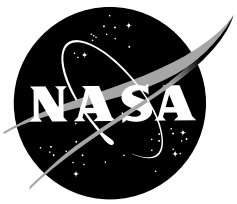
NASA Technical Memorandum 108848

Director's Discretionary Fund Report for Fiscal Year 1994

Ames Research Center

February 1995



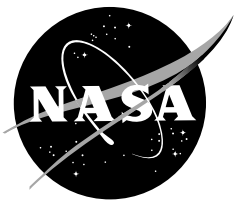
National Aeronautics and
Space Administration

NASA Technical Memorandum 108848

Director's Discretionary Fund Report for Fiscal Year 1994

Ames Research Center, Moffett Field, California

February 1995



National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, CA 94035-1000

CONTENTS

Section 2: Ongoing Reports

INTRODUCTION

The Director's Discretionary Fund (DDF) at Ames Research Center was established to fund innovative, high-risk projects in basic research that are essential to our future programs but otherwise would be difficult to initiate. Summaries of individual projects within this program are compiled and issued by Ames each year as a NASA Technical Memorandum.

These summaries cover 12 final projects and 21 ongoing projects in Fiscal Year 1994.

The contents are listed alphabetically according to the last name of the primary investigator in two sections (final and ongoing reports). Following the narrative reports, two appendixes (for final and ongoing reports) contain brief descriptions with the financial distribution and status of each of the projects.

Any questions can be addressed to an investigator directly.

SECTION 1
FINAL REPORTS

Laboratory Investigation of the Growth, Structure, and Apparent Phase Equilibria of Polar Stratospheric Clouds

Investigator(s)
David F. Blake, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

NASA's interest in this area of research is twofold: First, NASA is tasked under the Mission to Planet Earth with investigating the general impact of humankind's activities on Earth's ecosystems; second, NASA is conducting studies to evaluate the atmospheric effects of stratospheric aircraft.

The discovery of ozone depletion in the stratosphere (Farman et al., 1985) and the elucidation of the mechanism of its destruction have ranked as two of the most dramatic scientific discoveries of recent times. The chlorofluorocarbon (CFC)-induced depletion of ozone in the polar stratosphere is known to involve chemical reactions that occur on the surfaces of polar stratospheric cloud (PSC) particles (Solomon et al., 1986; Tolbert et al., 1987; Molina et al., 1987). However, the identity of the phases present in PSCs has been a matter of some uncertainty since natural PSC particles have never been analyzed. PSC particles are thought to be composed of nitric acid hydrates since these crystalline compounds are stable under the pressure, temperature, and composition (P,T,X) conditions prevalent where the clouds form. Laboratory studies of these compounds have been conducted to determine reaction rates, sticking coefficients, etc. on model PSC surfaces in order to constrain these parameters in atmospheric models. However, in many cases the structure of the solid phases used as model PSC substrates is not known (i.e., crystalline or amorphous, single or multiphase, single crystal or polycrystalline). Furthermore, the substrates themselves typically consist of flat layers of ice condensed inside tubes or flow reactors, physically quite unlike the submicron PSC particles they are intended to model.

The objective of this investigation is to directly identify the phases that exist within PSC ice particles grown under realistic conditions in the laboratory. We do this by growing PSC ice analogs under the same conditions as exist in the polar stratosphere and studying their structure using diffraction techniques. We hope that the results will help to clarify important issues such as the cause of the expansion of the Antarctic ozone hole, the likelihood of an Arctic ozone hole, and the possibility that observed ozone depletions above the midlatitudes will persist or become widespread. Once the phases present in PSCs are identified and their conditions of formation are known, we will be better able to assess the potential risks of various planned anthropogenic activities in the stratosphere.

Progress and results

A critical component of this investigation is the ability to deposit known ratios of gases such as water vapor and nitric acid vapor onto cold substrates suitable for viewing in an electron microscope. A gas mixing and gas inlet rack was designed, built, and interfaced to a vacuum station for this purpose. A sample insertion mechanism from an electron microscope was modified to fit into the chamber of the vacuum station. A cryotransfer sample holder from an electron microscope can be inserted into the chamber and used as a cold substrate for depositing ices. The frozen sample can then be removed from the deposition apparatus in its cryoholder, transferred to an electron microscope, and viewed in its pristine state.

Nitric acid hydrates are thought to be principal components of PSCs. The experiments we are presently conducting have as their goal the characterization of all the hydrates that exist within the nitric acid–water system. Crystal structures have been determined for the monohydrate (Luzzati, 1951) and trihydrate (Taesler et al., 1975), but nothing is known of the structure of the dihydrate or of the higher hydrates reported by others (Ritzhaupt and Devlin, 1991). Furthermore, the structural determinations of Luzzati and Taesler were performed on liquids crystallized inside capillary tubes under more or less equilibrium conditions. Natural PSC ices or PSC analog ices grown in the laboratory by vapor deposition may not achieve equilibrium during the time course of an experiment and may indeed be metastable phases quite different from the equilibrium products for which crystal structures have been determined.

In our experiments, vapor generated from nitric acid–water mixtures of specific compositions (Hanson and Mauersberger, 1988) is leaked into a chamber under high vacuum and deposited onto a thin carbon film as an amorphous ice at –170° C. The deposit is then warmed to –75° C or some other preselected temperature, at which time the material crystallizes. The stage is then rapidly cooled to –175° C so that no further changes occur in the ice, and the sample is

transferred in the frozen state to a specially equipped electron microscope. Our first experiments were to characterize the trihydrate for which at least two structures are suggested (Tolbert and Middlebrook, 1990), the α and β forms. A 3:1 water:nitric acid vapor mixture was leaked into the chamber and deposited onto the cold substrate. At low temperatures, the mixture was deposited as an amorphous solid and, when warmed above about 175° C, formed a crystalline material (fig. 1). This crystalline material, which has peaks at 8.64, 6.32, 5.46, 5.41, 4.61, 4.32, 4.13, 3.72, 3.56, and 3.38 Å, could not be identified as the trihydrate, and we assume that a different stoichiometry of water:nitric acid was produced by differing sticking coefficients of the two gas species on the cold substrate. These preliminary results were presented in Blake (1994). We believe that the material produced in these experiments is in fact the dihydrate of nitric acid, for which a crystal structure has not yet been determined.

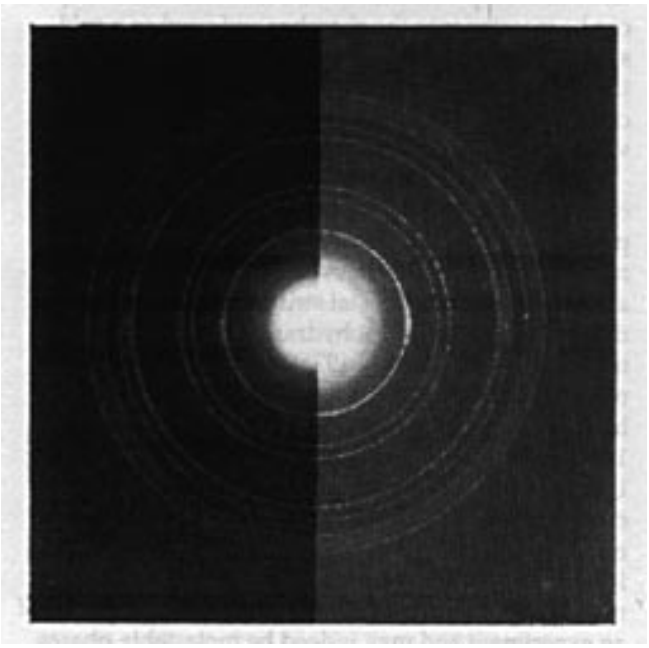


Figure 1. Diffraction pattern of 3:1 (nominal) water: nitric acid gas mixture, deposited at 115 K and annealed at 173 K for 15 minutes under mid-10^{-5} Torr range pressure. The sample was then cooled to 115 K and transferred to the electron microscope in the frozen state. The measured diffractions do not correspond to either the trihydrate or the mono hydrate. It is possible that the dihydrate of nitric acid was formed, but this phase has not yet been characterized by diffraction.

Significance of the results

The experiments described above represent our results to date. Although the technique appears to work, one needs to account for the sticking coefficients of the various gases at the temperatures of vapor deposition. There are additional problems associated with constrictions in the gas delivery system, which would create kinetic obstacles to gas equilibration, and the slow rate at which the icy solid changes phase at the low temperatures of the experiments.

In addition to demonstrating the ability of the deposition apparatus to perform experiments of this type, we have for the first time created a diffraction pattern characteristic of the structure of (we believe) the dihydrate of nitric acid. The results from this work are included in a proposal to the Innovative Research Program for formal funding. In future work, we will interface an infrared spectrometer to the deposition chamber so that the composition of the gas and the solid ice formed on the substrate can be determined. In this way, we will be able to compare our structural results directly to laboratory infrared spectra reported by others. In addition, we will be able to control for factors such as sticking coefficients and the like by directly analyzing both the gas and the as-deposited icy solid.

Publications resulting from study

Blake, D. F.: Laboratory Investigation of the Growth and Crystal Structure of Nitric Acid Hydrates by Transmission Electron Microscopy (TEM). Atmospheric Effects of Stratospheric Aircraft (AESA) meeting, Virginia Beach, Va., June 1994.

References

Farman, J. C.; Gardiner, B. G.; et al.: Large Losses of Total Ozone in Antarctica Reveal Seasonal ClO_X / NO_X interaction. Nature, vol. 315, 1985, pp. 207–210.

Hanson, D. R.; and Mauersberger, K.: Vapor Pressures of HNO_3 / H_2O Solutions at Low Temperatures. J. Phys. Chem., vol. 92, 1988, pp. 6167–6170.

Luzzati, V.: Structure Cristalline de L'acide Nitrique a une Molecule D'eau. Acta Crystollogr., vol. 4, 1951, pp. 239–244.

Molina, M. J.; Tso, T.; Molina, L. T.; and Wang, F. C. Y.: Antarctic Stratospheric Chemistry of Chlorine Nitrate, Hydrogen Chloride, and Ice: Release of Active Chlorine. Science, vol. 238, 1987, pp. 1253–1257.

Ritzhaupt, G.; and Devlin, J. P.: Infrared Spectra of Nitric and Hydrochloric Acid Hydrate Thin Films. J. Phys. Chem., vol. 95, 1991, pp. 90–95.

Solomon, S.; Garcia, R. R.; Rowland, F. S.; and Wuebbles, D. J.: On the Depletion of Antarctic Ozone. Nature, vol. 321, 1986, pp. 755–758.

Taesler, I.; Delaplane, R. G.; et al.: Hydrogen Bond Studies. XCIV. "Diaquaoxonium Ion in Nitric Acid Trihydrate." Acta Crystollogr., vol. B31, 1975, pp. 1489–1492.

Tolbert, M. A.; Rossi, Michel J.; Malhotra, R.; and Golden, D. M.: Reaction of Chlorine Nitrate with Hydrogen Chloride and Water at Antarctic Stratospheric Temperatures. Science, vol. 238, 1987, pp. 1258–1260.

Tolbert, M. A.; and Middlebrook, A. M.: Fourier Transform Infrared Studies of Model Polar Stratospheric Cloud Surfaces: Growth and Evaporation of Ice and Nitric Acid / Ice. J. Geophys. Res., vol. 95(D13), 1990, pp. 22 and 431.

Keywords

Polar stratospheric clouds, Ozone, Nitric acid hydrate

Monitoring Global Change During the Last 10,000 Years

Investigator(s)
Hector L. D'Antoni, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

To develop a method to link remote sensing data to modern pollen data, and to generate predictive tools and use them to hindcast paleoenvironmental data that can provide larger time windows to current models of global change.

Progress and results

A method was developed for calibrating modern pollen data in terms of remote sensing data. The proposed method is useful to predict radiometric data in regions (such as southern Patagonia) where the paucity of modern climate data is a major obstacle for research in paleoclimatology and paleoecology. The new reconstructions of past environments combine the rich information produced by pollen analysis with a simulation of remote sensing data of vegetation. Such simulation can be fed to models of global change that use remote sensing data of vegetation and thus bring their time frame from the current few decades up to several thousands of years. A paper describing this methodology was published in 1993 (D'Antoni and Spanner, 1993). A first application of the method to hindcast simple ratio vegetation index (SRVI) from fossil pollen data of postglacial sedimentary profiles of southern Argentina was discussed in San Diego at the 26th meeting of the American Association of Stratigraphic Palynologists (D'Antoni, 1992). An application of the method to hindcast the normalized differences vegetation index (NDVI) was discussed at the Third Symposium on South America, Landscape Development, Paleoecology and Climate History of the Arid Diagonal of South America in the Recent Quaternary, held at Bamberg University, Germany, in July 1994 (D'Antoni, 1994a). This contribution has been accepted for publication in a special issue of the Bamberger Geographische Schriften (D'Antoni, 1994b).

As an extension of my current research I made a detailed study of vegetation and climate maps, which produced the data necessary to conduct a paleoclimatic study of central Mexico. Whereas geologists held that about 2,500 years before the present (BP) there was a cold phase with glaciers extending over lower elevations, traditional palynological interpretation suggested a temperature rise and the establishment of temperate forests at 3,000 meters above sea level in central Mexico. By calibrating predictive equations I concluded that pollen also indicated a sharp temperature drop at 2,500 BP (D'Antoni, 1993).

Remote sensing data from the National Oceanic and Atmospheric Administration (NOAA-9) advanced very high resolution radiometer (AVHRR) from channels 1 (0.580–0.680 μ_m) and 2 (0.275–1.100 μ_m) were used to calculate albedo values at 74 stations across southern Patagonia and Tierra del Fuego (Argentina). These values were used to calculate vegetation indices (SRVI, NDVI) for each station. Remote sensing data were acquired on February 18, 1987, a few weeks after field work in Patagonia produced surface soil samples from all 74 stations. Soil samples were analyzed for their pollen content. Thus, each station had a remote sensing value (I used reflectance data from both channels 1 and 2 or vegetation indices) and a pollen spectrum (the pollen content of the sample in percentage of a total pollen sum). At this point, multiple linear regression (MLR) was used to calibrate pollen spectra in terms of remote sensing of vegetation. Since the relationships between pollen spectra and remote sensing data are not necessarily linear, linearization was performed in order to obtain better fitting while remaining within the framework of MLR, a methodology that is easy to use and very familiar to pollen analysts. Once a good model was available, it was loaded with fossil pollen data, and "paleo" remote sensing data were produced. A SRVI or NDVI value was thus calculated for each fossil sample. Seventy-four stations were studied in southern Patagonia and Tierra del Fuego for modern pollen content of the soil surface and 40 stations were similarly studied in central Oregon. Whereas human impact on the landscape was easy to identify in Argentine pollen spectra, the Oregon transect showed anomalies in modern pollen spectra that probably reflect the large impact of human action on natural vegetation. Therefore, I considered it safer to develop and test the new method on the South American database.

To illustrate the results of the paleoecological research I will discuss profile Meseta Latorre I (southern Patagonia). Meseta Latorre I was originally investigated by Frank Schäbitz (1991). For

calibrating the predictive models of Patagonia I used the PROPAL database developed under my guidance and remote sensing data from the AVHRR mounted on the NOAA-9 satellite.

A relative pollen diagram of profile Meseta Latorre I is used as a case in point. The site Meseta Latorre is a peat bog located at 51°31' S, 72°03' W, and 1,000 m above sea level, near the present upper timberline. Schäbitz (1991) considers that fluctuations of the *Nothofagus* curve (fig. 1) are related to temperature fluctuations. Zonation was performed with the CONISS algorithm for cluster analysis. Two zones were identified, each with several subzones.

Zone 1

Subzone 1. Four lower levels. Dominance of Cyperaceae, with minor proportions of Gramineae, *Empetrum* and *Nothofagus*. Mean hindcasted NDVI, mh-NDVI = 0.061 ± 0.067.

Subzone 2. Next eight levels. Dominance of Cyperaceae is slowly taken over by Gramineae and *Nothofagus*. The upper layer of this subzone is the end of Zone 1. mh-NDVI = 0.162 ± 0.035.

Zone 2

Subzone 1. Next four levels. *Nothofagus* becomes dominant accompanied by Gramineae, while Cyperaceae show reduced values. mh-NDVI = 0.213 ± 0.027.

Subzone 2. Next six levels. *Nothofagus* is at its highest values in the profile. Cyperaceae are at their lowest. Gramineae are around 20 percent. mh-NDVI = 0.250 ± 0.017.

Subzone 3. Next six levels. *Nothofagus* is dominant accompanied by Gramineae. There is a significant increase of Cyperaceae. mh-NDVI = 0.220 ± 0.014.

Subzone 4. Next three levels. *Nothofagus* is dominant and both Gramineae and Cyperaceae show reduced proportions. mh-NDVI = 0.250 ± 0.015.

Subzone 5. The upper three levels. Small retreat of *Nothofagus* and Cyperaceae and a strong advance of Gramineae. mh-NDVI = 0.239 ± 0.012.

The postglacial history of vegetation at this latitude is significant because the period between 9,055 ± 140 years BP and about 4,000 BP has open vegetation of Cyperaceae with geophytic life form, well adapted to cold winters, thus reflecting an Andean location above the upper timberline. After that time, the expansion of *Nothofagus* forests shows a more benign climate. The mh-NDVIs show that soil coverage is moderate throughout the whole profile. However, the mh-NDVI crosses the thresh old of 0.200 about 5,100 years BP, a fact that we interpreted as an indication that the forest occupied Meseta Latorre and has remained there to the present.

Hindcasted NDVIs provide a solid description of vegetation when combined with traditional fossil pollen data. The proposed methodology will produce a more realistic reconstruction of past environments when 'snapshots' of remote sensing data of vegetation are replaced by time-series of data. These reconstructions made in terms of vegetation indices (NDVI) are used to describe modern vegetation from remote sensing data. Thus, past and present studies of vegetation can be related using the same codes. Models of global change can use simulations based on studies of paleovegetation to enlarge their currently short time frame.

This project produced a large amount of original data and an extensive database was developed by reviewing the early works of H. P. Hansen (Hansen, 1946) for Oregon and Washington. The modern pollen database for central Oregon is close to completion. I studied all the profiles published by Hansen and generated new statistics and diagrams that allow interpretation using modern techniques. These changes allow a direct comparison with profiles dated by C. J. Heusser for Oregon and Washington. Also in progress is our interpretation on our studies of racemization of aspartic acid in peat profiles of southern Patagonia and Tierra del Fuego.

My interest for South American ecology as well as interaction with several colleagues at the Ames Research Center led me to initiate a research program on the effects of stratospheric ozone depletion and increased levels of ultraviolet (UV) radiation on Subantarctic forests and western Patagonian steppe. I suggested performing field work in regions where increases in UV radiation were detected or suspected, by subtracting part of the current UV radiation to simulate conditions under 0 percent ozone depletion. A project was written by a group of collaborators, reviewed by 20 highly qualified American and foreign UV-B specialists, and published (D'Antoni et al., 1994).

Publications resulting from study

D'Antoni, H. L.; and Spanner, M. A.: Remote Sensing and Modern Pollen Dispersal in Southern Patagonia and Tierra del Fuego (Argentina): Models for Palaeoecology. Grana, vol. 32, 1993, pp. 29–39.

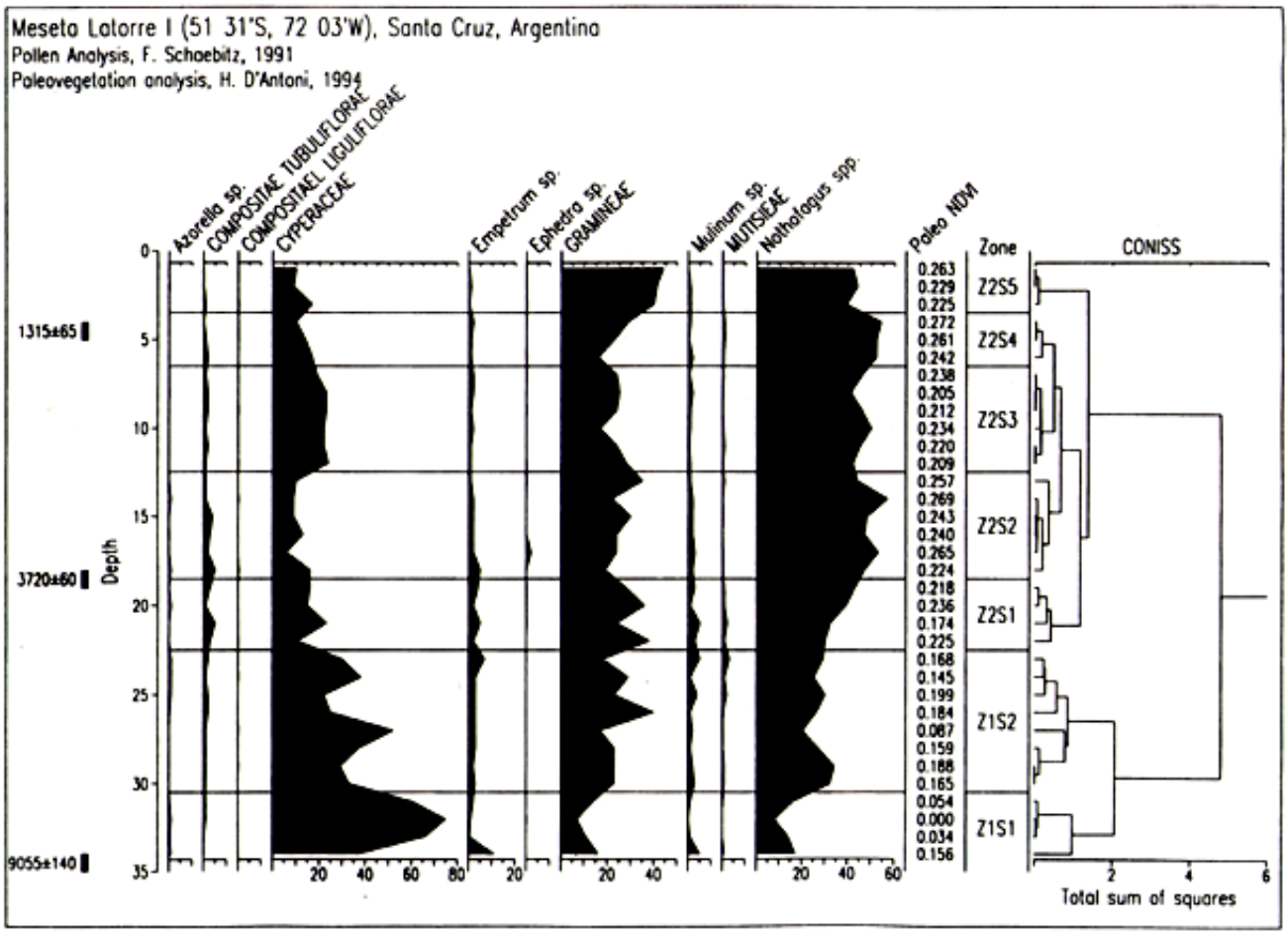


Figure 1. Relative pollen diagram for Meseta Latorre I.

D'Antoni, H. L.: Pollen Analysis in Southern Patagonia: From Space to Time. Paper presented at the 26th Meeting of the American Association of Stratigraphic Palynologists, San Diego, Calif., 1992.

D'Antoni, H. L.; Armstrong, R.; Coughlan, J.; Skiles, J.; and Daleo, G. R.: Remote Sensing and Palaeoecology in Southern Patagonia. Proceedings of the 3rd Symposium on South America, Landscape Development, Paleoecology and Climate History of the Arid Diagonal of Southern America in the Recent Quaternary, Bamberg, Germany, July 1994.

D'Antoni, H. L.: Paleotemperatures of La Malinche: A Palynological Hypothesis. Grana, vol. 32, 1993, pp. 354–358.

D'Antoni, H. L.; Armstrong, R.; Coughlan, J.; Skiles, J.; and Daleo, G. R.: Effects of Stratospheric Ozone Depletion and Increased Levels of Ultraviolet Radiation on Subantarctic Forests and Western Patagonian Steppe: A Research Project in Stratospheric Ozone Depletion / UV-B Radiation in the Biosphere, R. H. Biggs and M. E. B. Joyner, eds., NATO ASI Series I, vol. 18, Springer-Verlag, Berlin, 1994, pp. 81–96.

References

D'Antoni, H. L.: Pollen Analysis in Southern Patagonia: From Space to Time. Paper presented at the 26th Meeting of the American Association of Stratigraphic Palynologists, San Diego, Calif., 1992. (Paper in preparation to publish in Palynology.)

D'Antoni, H. L.: Paleotemperatures of La Malinche: A Palynological Hypothesis. Grana, vol. 32, 1993, pp. 354–358.

D'Antoni, H. L.; Armstrong, R.; Coughlan, J.; Skiles, J.; and Daleo, G. R.: Remote Sensing and Palaeoecology in Southern Patagonia. Proceedings of the 3rd Symposium on South America, Landscape Dvelopment, Paleoecology and Climate History of the Arid Diagonal of Southern America in the Recent Quaternary, Bamberg, Germany, July 1994.

D'Antoni, H. L.: Remote Sensing and Palaeoecology in Southern Patagonia. Proceedings of the 3rd Symposium on South America, Landscape Development, Paleoecology and Climate History of the Arid Diagonal of Southern America in the Recent Quaternary, Bamberg, Germany, July 1994b. Paper accepted for publication in the Bamberger Geographische Schriften.

D'Antoni, H. L.; Armstrong, R.; Coughlan, J.; Skiles, J.; and Daleo, G. R.: Effects of Stratospheric Ozone Depletion and Increased Levels of Ultraviolet Radiation on Subantarctic Forests and Western Patagonian Steppe: A Research Project in Stratospheric Ozone Depletion / UV-B Radiation in the Biosphere, R. H. Biggs and M. E. B. Joyner, eds., NATO ASI Series I, vol. 18, Springer-Verlag, Berlin, 1994, pp. 81–96.

D'Antoni, H. L.; Skiles, J.; Armstrong, R.; Coughlan, J.; Daleo, G.; and Mayoral, A.: Plant Responses to Increased UV-B Radiation: A Research Project. The 5th Global Warming International Conference and Expo, San Francisco, Calif., Apr. 4–7, 1994. Abstracts: 92. (Poster session with a booth devoted to the first results of this project.)

D'Antoni, H. L.; and Spanner, M. A.: Remote Sensing and Modern Pollen Dispersal in Southern Patagonia and Tierra del Fuego (Argentina): Models for Palaeoecology. Grana, vol. 32, 1993, pp. 29–39.

Hansen, Henry Paul: Pollen Analysis and Postglacial Climate and Chronology. Science Monthly [Early Man in Oregon], vol. 62, no. 1, Jan. 1946, pp. 52–62.

Schäbitz, F.: Holocene Vegetation and Climate in Southern Santa Cruz, Argentina, Bamberger Geographische Schriften, Bamberg, Germany, Bd. 11, 1991, pp. 235–244.

Keywords

Paleoclimate, Historical global change, Paleovegetation, and Paleoecology

Schmidt-Cassegrain Long-Range Laser Velocimeter

Investigator(s)
Stephen E. Dunagan, Ames Research Center, Moffett Field, CA 94035-1000

Objectives of the study

Many large scale aeronautical test programs that are conducted in the National Full-Scale Aerodynamics Complex (NFAC) wind tunnels require the measurement of localized regions of the flow field in order to better understand the aerodynamic phenomena under investigation. Laser velocimetry (LV) is an important noninvasive method for measuring the air velocity at a point. This study has been directed at the design and fabrication of an instrument for the 40- by 80-Foot Subsonic Wind Tunnel. Technical challenges include test section access, adequate optical aperture, laser power, and flow seeding techniques. Instrument design parameters combine to determine the signal-to-noise ratio of the product instrument, which ultimately determines the achievable data rates and therefore the economic viability of the instrument.

Progress and results

A two-component, dual-beam laser velocimetry (LV) system for the 40- by 80-Foot Subsonic Wind Tunnel has been designed and fabricated and is undergoing final testing in the optics lab. The instrument design is based on the adaptation of commercial large aperture Schmidt-Cassegrain telescope optics to simultaneously perform the functions of focusing the laser beam pairs to a beam waist intersection defining the measurement (probe) volume, and collecting the back-scattered light and focusing it through a spatial filter to an appropriate photodetector. Uncoupled orthogonal measurement of two coordinates of velocity may be made with this instrument. To avoid the need for large, high quality windows in the test section, the instrument has been configured as a streamlined optical assembly mounted to a traverse on the floor of the test section and translated in the streamwise and cross-stream directions.

The layout of the instrument is depicted in figure 1. Single-mode polarization maintaining fiber-optics transmit light from the remotely located laser into the optical assembly. The laser velocimeter probe volume is translated in the vertical direction by means of the zoom (focusing) feature of the primary mirror of the telescope. The optical power combination of the primary and secondary mirrors is ideal for creating a small, high intensity probe volume. Coaxial back-scattered light is collected through the same optical system. The small probe volume and excellent imaging performance of the telescope optics permit this collected light to be spatially filtered through an appropriately sized pinhole to reject unwanted light scattered from outside the laser beam intersection volume, thereby improving the signal-to-noise ratio. This spatially filtered signal is then conveyed via multimode fiber to a photomultiplier tube, and the electronic signal is analyzed with a commercially available Fourier transform processor for Doppler shift. Frequency domain signal processing permits analysis of Doppler burst signals with a very poor signal-to-noise ratio.

A prototype optical system has been set up and evaluated on the optics bench. Results have been encouraging, with high signal-to-noise ratio as the primary indicator. Some problems have been identified as well; in particular, the very small number of fringes present in the probe volume is problematic for the commercial digital Fourier-transform burst-signal processor in use. A wind tunnel instrument has been designed and fabricated based on the outcome of this optical bench test. A stress analysis for the test section mounted instrument pod and a small scale traverse has been completed. Fabrication drawings have been generated and the components have been fabricated. The instrument has been assembled in the optics lab and evaluated with a calibration velocity source and an air jet flow field.

Significance of the results

Results of the instrument checkout prove the viability of the design concept. This study has produced an instrument suitable for on-demand use in a variety of testing applications in the large NFAC wind tunnels.

Publications resulting from study

Dunagan, S. E.: A Long Range Schmidt-Cassegrain Laser Velocimeter for Large Wind Tunnel Applications. AIAA Paper 94-0019, to be presented at the AIAA 33rd Annual Aerospace Sciences Meeting, Reno, Nev., Jan. 1995.

Keywords

Laser Doppler velocimeters, Flow measurement, Wind tunnels

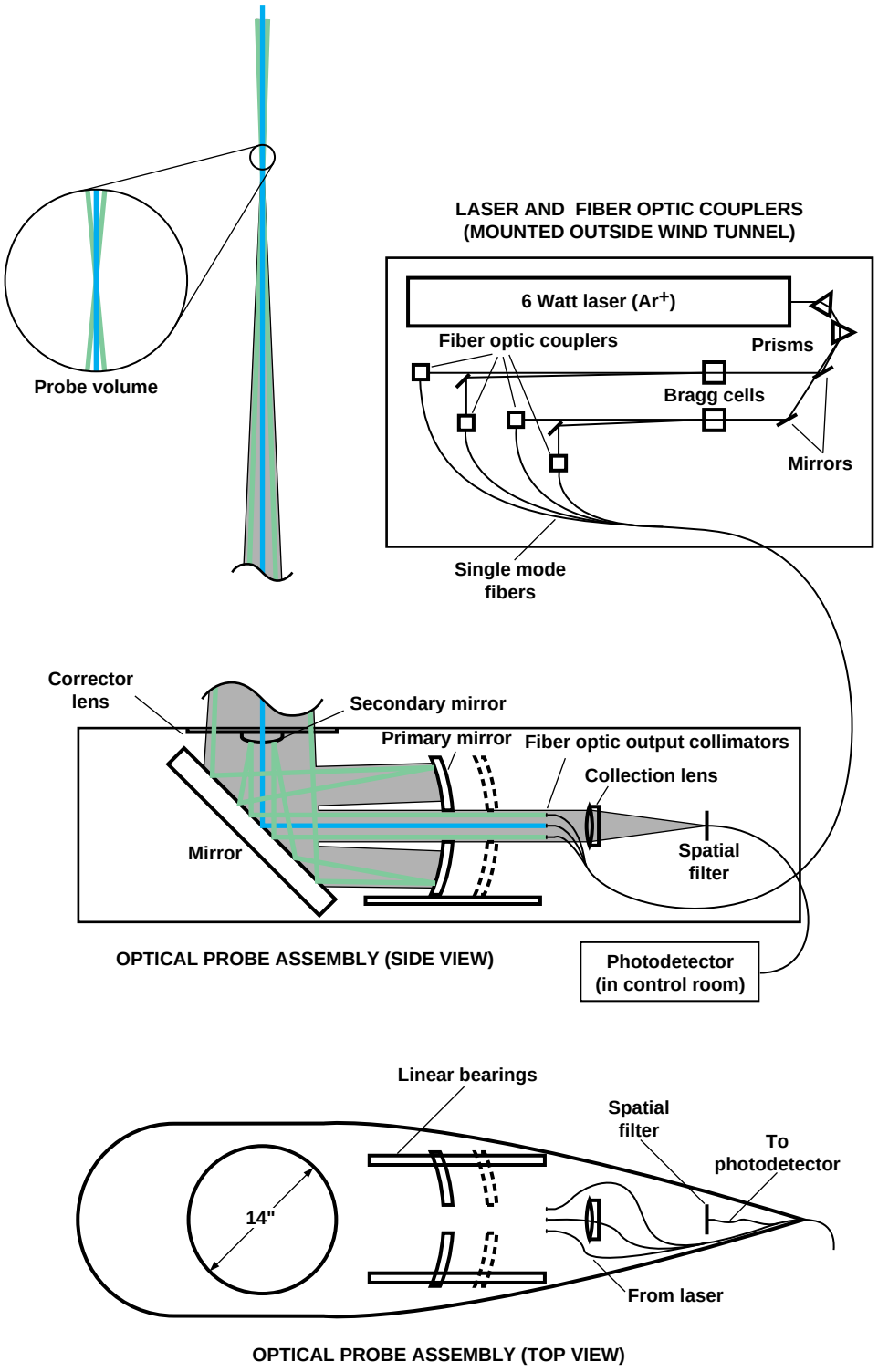


Figure 1. Optical layout for Schmidt-Cassegrain long- range laser velocimeter.

Detection of Life Forms: Extant, Dormant, or Extinct

Investigator(s)
Rosalind A. Grymes and Christine Sawyer,
Ames Research Center,
Moffett Field, CA 94035-1000
Jay Shafto, Pomona College,
Claremont, CA 91711

Objectives of the study

Researchers continue to be intrigued by questions surrounding terrestrial evolution, by the reality of life in extreme terrestrial environments, and by the possibility of extraterrestrial life. The fossil record and extant unicellular organisms, like the Archaebacteria, are links to the origins of life on Earth. Studies of simple organisms surviving in environments such as the Gobi Desert and the Antarctic ice fields enable us to form hypotheses regarding the presence of life in conditions nearly as harsh as those of some planetary surfaces. In this project, we have applied one of the newest and most powerful technologies of molecular biology to the central difficulty scientists encounter in the search for life-recognizing success. We have experimented with a technique that can detect both extant and extinct life. The polymerase chain reaction (PCR) enzymatically amplifies nucleic acids. With the particular exception of prions, all life on Earth is based on the genetic code of the nucleic acids deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). In PCR, a thermostable DNA polymerase makes a faithful copy of any DNA molecule–even DNA fragments can be substrates. The 'chain' of the reaction's title refers to the sequential rounds of molecular polymerization that occur every 1–2 minutes for 20–30 cycles. Figure 1 shows schematically the amplification of a DNA sequence by PCR. Amplifications on the order of 10^5-fold can be regularly achieved, and higher levels of amplification are attainable if required.

From the space agency's viewpoint, the search for life can more accurately be termed the search for microscopic life or remnants of life. Larger forms of plant and animal life are unmistakable, but are unexpected in extreme terrestrial and extraterrestrial environments. In dealing with microscopic organisms, the techniques used for isolation and detection have important limitations. Isolation from environmental sampling requires cultivation and the maintenance of an acceptable habitat. The environmental conditions of thermal springs, deep sea trenches, desert rocks, and Antarctic tundra are very difficult to faithfully recreate in the laboratory. Each of these individual niches is described by unique variables of moisture, pH, available oxygen, temperature, etc. NASA researchers face an even more daunting challenge, as the conditions required by extraterrestrial life forms are completely unknown. In the area of detection, clinical techniques are based on 1) the chemical detection of specific products that can be associated with particular organisms, and 2) unique organismal metabolic requirements or capabilities. Researchers are not usually well informed about the attributes of life forms that are rare or alien.

The PCR offers two distinct advantages over the more classic approaches described above. First, it unites the detection of nucleic acids with their amplification. Even a single molecule of DNA is sufficient to initiate the reaction. Second, it can detect any life form using the DNA/RNA genetic code. No other information regarding metabolism, cultivation conditions, or products is required. The power of this technology is already being exploited by archaeologists in recovering the genetic code of organisms long extinct from partial DNA residues in fossils. The requirements that we have studied differ from those of most biological historians, however. PCR depends on the initiation of the reaction using a 'primer' supplied by the experimenter. Usually, researchers are interested in a specific DNA or RNA sequence, and will provide a primer based on their knowledge of that sequence. We have evaluated the utility of the PCR reaction using random primers to identify unknown DNA sequences. Our initial investigations have focused on:

- selecting primer pairs that amplify an identifiable pattern from test bacteria;
- evaluating parameters affecting the results;
- determining the finest level of detection that can be attained; and
- recovering detectable signal patterns from test bacteria adsorbed to solid surfaces (soil samples and soil sample mock-ups).

Progress and results

Selecting primer pairs that amplify an identifiable pattern from test bacteria

Evaluating parameters affecting the results

The primers listed in table 1 were tested for their ability to amplify a ladder of DNA fragments from genomic DNA isolated from Escherichia coli (E. coli), a

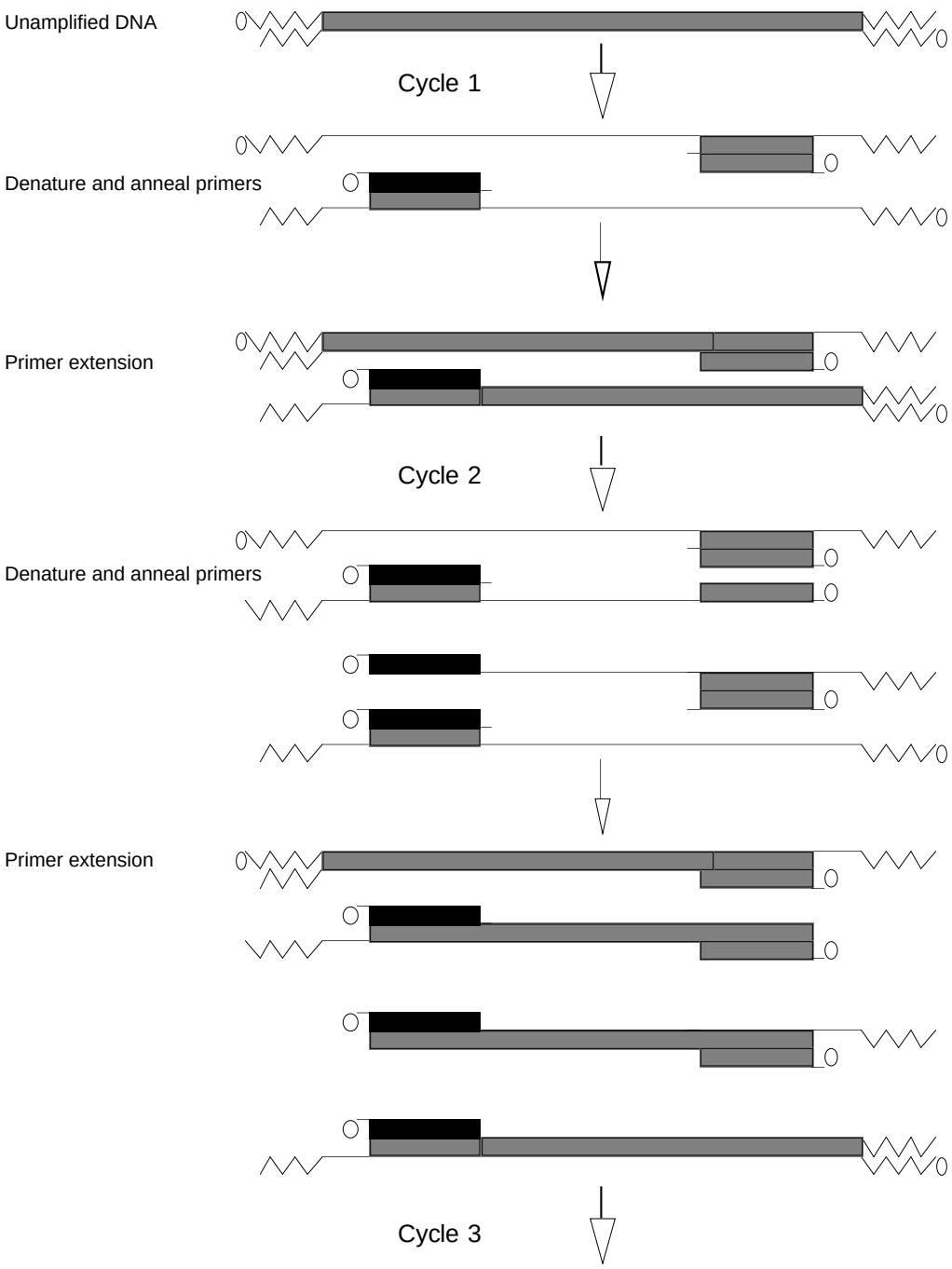


Figure 1. Polymerase chain reaction.

Table 1

Designator	Melting point, °C	At composition, percent	Sequence
RE-01	49	20	CGGGATCCGC
RE-02	45	20	GCGGTACCCG
RE-05	41	40	GCGAATTCCG
RE-06	41	40	CGGAATTCGC
RE-07	47	20	GGGATCCGCC
RE-10	44	20	CCCTGCAGGC
RE-21	47	20	GGCTGCAGCG
RE-22	43	20	CCCTCGAGGC
RE-24	46	20	GGTCGACGCG
RE-25	41	20	CGAATTCGGC
RE-26	52	20	CCGCATGCGC
RE-30	47	20	CGCGAGCTCG

bacterium commonly found in soil and in the mammalian lower intestinal tract. This bacterium was selected because it is frequently used in laboratory investigations for genetic engineering applications, and the strain used had been mutated so that it was entirely dependent on nutrients supplied in the laboratory. This strain would be unable to survive in the wild. The primers were selected because they have compatible melting points. The thermal energy required to disrupt duplex DNA, to 'melt' it apart, depends on the relative amounts of the four bases (A = Adenine, T = Thymidine, G = Guanine, C = Cytidine) that make up a particular DNA sequence. The strongest duplex bonding occurs between G and C, so higher percentages of A/T correlate with lower melting points. Temperature selection is an important part of the PCR process, as detailed below.

The PCR process contains fundamentally four steps that operate on the required components. The components are:

- substrate DNA (E. coli genomic DNA)
- primer (one of the primers above)
- nucleic acid building blocks (adenine, thymidine, guanidine, cytidine deoxyribotriphosphates)
- thermostable DNA polymerase
- magnesium (a required cofactor of the enzyme)

The required steps are:

- heat the reaction (denature the substrate)
- cool, and maintain at the annealing temperature that permits association of the primer with the substrate
- step to the temperature that allows efficient operation of the DNA polymerase, and stay at that temperature long enough to elongate the product DNA
- repeat this cycle, producing a doubling of product in each round

The first analysis of 12 primers resulted in successful amplification of resolvable fragments in 6 of the reactions. Amplified fragments result when the supplied primer pairs with the substrate DNA stably and within a distance of approximately 2,000 bases. The resulting amplified sequences are resolved by size and electrical charge (the molecules have a negative charge) by electrophoresis in agarose gels. Figure 2 shows, on the right, a cartoon of the electrophoresis hardware, with the positive and negative electrodes indicated. A gel of agarose is cast on the middle platform, and the gel is submerged in a buffer solution. DNA containing samples are loaded in the wells, and the resulting separation by size and charge that occurs by electrophoretic molecular sieving is indicated by the gel caricature on the left. DNA from different strains of E. coli amplified in the PCR process using the same random primer could yield the patterns indicated. Individual bands are assigned molecular sizes by comparison to bands of known size (markers) run in the adjacent land on the far right of the gel. Subsequently, we evaluated the contribution of magnesium concentration and annealing temperature to the amplification reaction. We determined that a magnesium concentration of 3.5 mM (high relative to many PCR protocols) was optimum in our system. At this level, the reactions produced both strongly amplified fragments and lesser quantities of more weakly amplified products. The experimenter can choose whether s/he wishes to see a complete 'catalog' of amplified fragments (high magnesium) or a more selective assortment of the most highly amplified fragments only (low

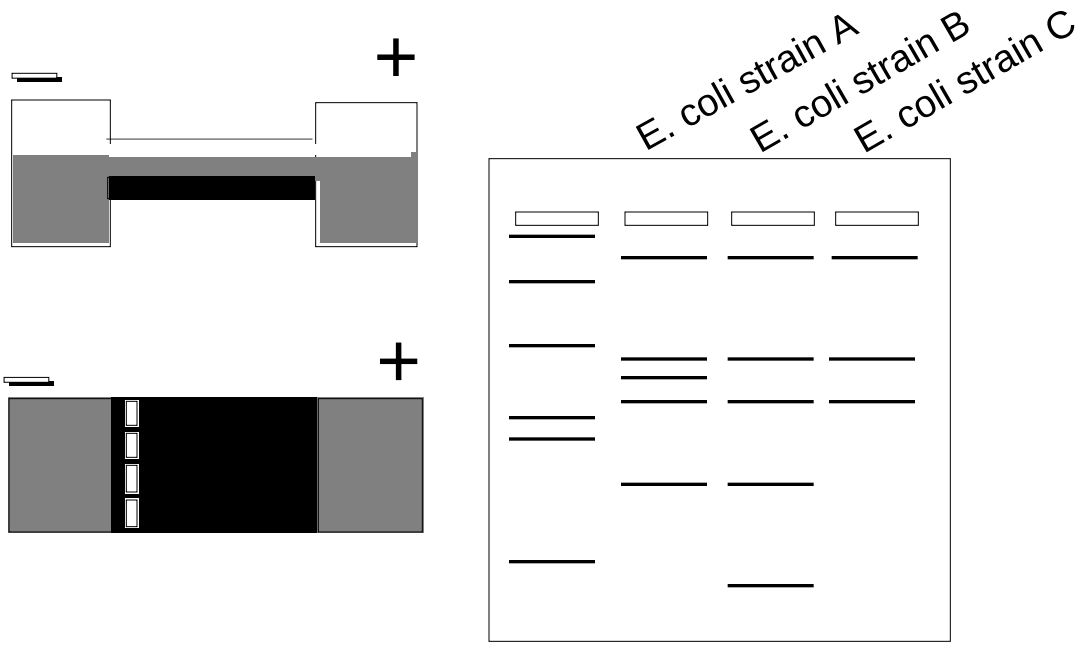


Figure 2. Diagrams showing the nature of electrophoretic molecular sieving analysis.

magnesium). Alterations of temperature similarly produce low levels of minor amplification products in addition to the main products seen under stringent conditions. This is due to altered binding of primer encouraged by the less stringent annealing temperatures, which allows more 'breathing' in the duplex pairs (primer:substrate).

Determining the finest level of detection that can be attained

This task was approached in two ways. First, nucleic acid that was isolated from E. coli cultures was used to prime amplification reactions, and serial dilutions were evaluated. In this way, we determined that as little as 0.5 nanogram of added substrate DNA resulted in the production of predicted fragment profiles using our standard conditions. Further sensitivity can be acquired by altering magnesium concentration and temperature, as discussed above, or by using the products of the amplification reaction as the substrate for a subsequent amplification process (sequential amplifications). Second, we tested the robustness of the PCR reaction by supplying the input DNA in its native packaging—we directly added samples of overnight broth cultures of E. coli to the reactants. The bacteria were lysed directly in the reaction mixture using an initial high temperature step (lysis by boiling). In this way, we were able to detect amplification products from as little as one microliter of an overnight culture. We also tried to correlate direct quantitation of bacteria (colony counting by placing a measured quantity of the liquid culture onto a solid substrate), spectrophotometric quantitation of bacteria (measurement of light-scatter at 600 nanometers), and PCR quantitation of bacteria (detection of amplification products). We found that direct colony counting required high sample dilutions to allow efficient visual counting, whereas spectrophotometry had a very short linear range, and could not detect highly diluted samples. In our hands, direct quantitation by PCR also had a limited effective range. One microliter of an overnight culture typically contains 100 bacteria. Volumes greater than 40 microliters could not easily be accommodated by our reaction mixture. We tested several volumes between 1 and 40 microliters, with no amplification success. We believe this is caused by overloading the reaction mix with bacterial lipids and proteins. In sum, the three methods of bacterial quantitation described overlap in utility, but no two had superimposed reliability ranges.

Recovering detectable signal patterns from test bacteria adsorbed to solid surfaces (soil samples and soil sample mock-ups)

Several different approaches were tried in the mock-up test. They were based in published protocols used to analyze soil bacteria or to evaluate PCR sensitivity in the arena of soil testing. Very little information

regarding the soil makeup was presented. Fundamentally, these procedures involve

- lysis of bacteria in the sample by heating, or no lysis, followed by
- emulsification of the soil sample in the presence of high calcium levels
- the addition of an equal volume of a high density material and
- low speed centrifugation of the sample.

The protocol is designed to release the bacterial particles from the soil, and have them float to the top of the density gradient during the centrifugation step, while the heavier soil solids form a pellet. We tried this procedure, and minor modifications, several times without success. The soil we used did not pellet cleanly, and there were major losses in bacterial viability. This may be due to osmotic shock as the bacteria are admixed with the high density fluid. We noticed a strong similarity between this protocol and the use of pure hydroxyapatite to bind DNA under specific ionic conditions. In these procedures, the nucleic acid is separated from complex mixtures by adsorption to the hydroxyapatite and is released by washing the bound complex with solutions of progressively changing ionic strength. We accordingly generated a protocol for the isolation of bacterial DNA from inoculated soil samples and raw samples patterned on hydroxyapatite resolution of DNA in mixed samples. This approach, too, was unsuccessful. It is clear to us that at this point we need additional expertise from geochemists to properly develop separation protocols that are capable of recovering fragments of nucleic acid from soil samples. The soil itself has ionic and colloidal properties that strongly affect our ability to manipulate adsorbed or admixed DNA. Existing laboratory procedures accommodate crude cell extracts, but are not robust enough to deal with the 'dirty' mixtures of soil sampling.

Significance of the results

We have demonstrated the applicability of PCR amplification to the study of samples containing unknown DNA sequences using the random priming approach. The efficiency and sensitivity of the process appear to be adequate to the task of detecting life in extreme environments. Water samples should present very little difficulty, but solid samples require methods of nucleic acid extraction. At the present time, these methods are beyond our expertise, although we are confident that this difficulty could be surmounted with only the addition of new technical expertise. We hope that this laboratory will continue to exist as a source of molecular biology tools to the NASA community.

Keywords

Random primed polymerase chain reaction (PCR), Molecular biology, Search for life

Determination of Polar Stratospheric Cloud Onset Over Antarctica Using Cloud Top Temperature Retrievals from the NOAA Advanced Very High Resolution Radiometer (AVHRR) Satellite Imagery

Investigator(s)
Steve Hipskind, Ames Research Center,
Moffett Field, CA 94035-1000
Kathy Pagan, San Francisco State University,
Ames Research Center
Oswaldo Garcia and Patricia Foschi,
San Francisco State University,
San Francisco, CA 94132
Steve Gaines, Sterling Software,
Ames Research Center

Objectives of the study

Polar stratospheric clouds (PSCs) occur during the polar winter when temperatures in the stratosphere fall to levels low enough to saturate the air with respect to nitric acid and/or water. The role that PSCs play in the chemistry of ozone depletion and the formation of the Antarctic ozone "hole" has been well documented (McCormick et al., 1982; Solomon et al., 1986; Turco et al., 1989; Hamill and Toon, 1991). PSCs provide the surfaces upon which heterogeneous reactions occur that ultimately lead to the destruction of ozone. The timing of the onset and duration of PSCs, as well as their geographic extent, are not well understood.

To date, no extensive or detailed climatology of PSCs has been assembled. Such a climatology would be an important tool in the study of ozone depletion in the polar regions and would establish baseline conditions from which changes in the frequency and occurrence of these clouds could be measured. Such changes may arise naturally or from human activity, such as the injection of nitric acid and water vapors into the stratosphere by future supersonic aircraft.

The relative lack of traditional meteorological observations in the Antarctic region makes it necessary to rely on satellite data in order to construct a long-term climatology of PSCs. The advanced very high resolution radiometer (AVHRR) sensors onboard the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites have been collecting data over the polar regions since 1979 (Burroughs, 1991). These operational satellites, with their excellent temporal and spatial coverage of polar regions, could be used to establish a PSC climatology if a means were found to reliably detect the presence of PSCs using AVHRR data.

Conventional wisdom (Yamanouchi et al., 1987; Ebert 1987a,b, 1989; Welch et al., 1992) held that AVHRR imagery is not suitable for PSC detection because these clouds occur during the polar winter and early spring, when little or no sunlight is present, thus making reflected channels useless. In addition, many PSCs are optically thin and occur against a cold background. Therefore there is often little thermal contrast between PSCs and the surface, making it very difficult to detect PSCs using infrared AVHRR data.

Recent research in the fields of remote sensing and image processing, however, has shown that AVHRR data can be successfully used to identify a variety of clouds over the polar regions using multispectral data (Yamanouchi et al., 1987) and various pattern-recognition algorithms based on spectral and textural features (Ebert 1987a, b, 1989; Key 1990; Welch et al., 1992). Ebert (1987b) took the first steps in the development of an algorithm that specifically identifies optically thick PSCs among 17 other categories of clouds. This algorithm, however, was only applied to data for a few days over both polar regions.

The objectives of this study are to determine whether AVHRR data can be used to detect both optically thick and optically thin PSCs over Antarctica for an entire season (1992). Information from the analysis of an entire season will be used to construct an automated classification scheme for the identification of PSCs. The development of an automated PSC detection scheme will allow processing of the entire record of AVHRR data in order to assemble a long-term climatology of PSCs.

Progress and results

AVHRR data obtained from the Arctic and Antarctic Research Center at the Scripps Institution of Oceanography was processed at the Ames Research Center using the Ames Meteorological Satellite Downlink and Display System. Several hundred AVHRR channel 5 (12 micron) images for the period of April–October 1992, were processed. NOAA AVHRR channel 5 data frequently contain random scanner

noise, randomly scattered single pixels, or small patches of pixels with anomalous values that are much darker or brighter than their neighbors. These anomalous pixel values are usually radiometrically corrected by globally using a median filter. Although this process is acceptable for most applications, the need to preserve the subtle differences in original values necessitated the development of another method. The new method uses two filters in tandem: one to mark anomalous pixels, selecting them by a local-difference algorithm, and a second to radiometrically correct only the marked pixels, using a median filter. Once the imagery was filtered, calibrated, and registered, temperatures in the PSC ranges were highlighted in color, and the evolution of these temperatures over an entire season (1992) was studied.

As surface temperatures in Antarctica can fall to PSC range, surface automatic weather station (AWS) data (Charles Stearns, University of Wisconsin, personal communication) and available National meterological Center (NMC) sounding data were used to help distinguish surface temperatures from tropospheric and stratospheric temperatures. Stratospheric temperature and aerosol extinction coefficient data from the cryogenic limb array etalon spectrometer (CLAES) instrument (John Mergenthaler, Lockheed Missiles & Space, Inc., personal communication) were also used to verify the results from the AVHRR temperature analyses.

Imagery from the 1992 season was analyzed and then divided into one of the four following categories for future study: 1) no PSCs—AVHRR temperatures represent cold Antarctic surface; 2) optically thick PSCs evident in the AVHRR imagery; 3) optically thin PSCs evident in the AVHRR imagery when verified with ancillary data sets; and 4) no PSCs evident in the AVHRR imagery, but PSCs are evident in the ancillary data sets.

From the initial analysis, it was determined that optically thick, and some optically thin, PSCs are easily identifiable in the imagery collected at Palmer Station, a station that collects AVHRR data for an area covering the Antarctic Peninsula and the Weddell Sea (approximately the area from 0° to 90°W, south of 60°). Type III PSCs (wave cloud PSCs) typically appear over the Weddell Sea, downwind of the topographic relief of the Antarctic Peninsula. The thermal contrast between PSCs and the underlying clouds and ground is the greatest in this region as compared to the colder interior portions of the continent, a fact which aids in the detection of PSCs.

Based on the results above, it was determined that image segmentation by geographic region would be the first step in the automated classification procedures. Various analyses of the imagery from Palmer Station have been performed to gather information to be incorporated into the automated classification scheme. The initial analysis of the data consisted of thresholding of PSC temperatures, constructing time series graphs, and compositing of images to show before, during, and after PSC events.

Three threshold temperatures (200 K, 195 K and 188 K) that encompass the brightness temperatures of both opaque and semitransparent PSCs were chosen. Areas with brightness temperatures colder than the selected thresholds were then identified and mapped for every AVHRR image collected at Palmer Station during August 1992. Time series graphs of the areal coverage of temperatures below each threshold were then constructed. This gave initial information on the overall temporal variability of PSC coverage for the region and guided the selection of particular time periods for compositing. Four PSC events were noted during August 1992. Images representing the before, during, and after PSC events were composited in order to yield information about the geographical distribution of the onset, evolution, and decay of PSCs in that region.

The second phase of analysis has begun; it consists of using neural networks for pattern recognition to aid in the identification of PSCs. Again, using AVHRR channel 5 data collected during August 1992 at Palmer Station, 62 files were assembled. Each file is a mosaic of the images collected for each 12 hour period that month. Where images overlapped, the minimum value of the various images was chosen. This process yields data sets that are more interpretable by visual inspection and by computer processing with a neural net. Using software that allows for a hypertemporal analysis of the channel 5 data, the time series of each pixel (temperature evolution over time) is plotted to identify the pattern and duration of PSC episodes. This information will be used to train a backpropagation neural network to locate PSC episodes by an automated method. The output from the neural network will be mapped to show the timing and geographic extent of each episode.

CLAES data were used to verify the presence of PSCs in both the analyses described above. CLAES data, and data from various other sensors aboard the Upper Atmospheric Research Satellite (UARS) will be used to verify the presence of PSCs in the AVHRR data for the entire 1992 season. Analyses of the AVHRR data will be expanded to cover the entire region of Antarctica for the 1992 season. The information gathered from the joint analyses of AVHRR and UARS data will be used to construct the automated classification scheme for PSC detection.

Significance of the results

The results from this initial study have shown that optically thick PSCs, and a portion of optically thin PSCs, can be readily identified in AVHRR imagery collected at Palmer Station, Antarctica. As the analysis of AVHRR is expanded to cover the entire Antarctic region, and various techniques such as neural networks, multispectral analysis, and textural analysis are incorporated, an automated classification scheme for PSC detection can be developed. This will enable the construction of a long-term climatology of PSCs. Such a climatology would enable researchers to begin to answer questions about the timing, onset, and duration of PSCs, as well as questions concerning their geographic extent and annual variability.

Publications resulting from study

Pagan, K.; Garcia, O.; Foschi, P.; Mergenthaler, J.; Kumer, J.; Roche, A.; Gaines, S.; and Hipskind, R. S.: Detection of Polar Stratospheric Clouds over Antarctica Using AVHRR, CLAES, Radiosonde and Surface Automatic Weather Station Data. Seventh Conference on Satellite Meteorology and Oceanography, Preprint Volume, Monterey, Calif., June 1994, pp. J19–J22.

Garcia, O.; Pagan, K.; Foschi, P.; Gaines, S.; and Hipskind, R. S.: Detection of Polar Stratospheric Clouds Over Antarctica Using AVHRR Images Obtained at Palmer Station During August 1992. Under review by the Polar Record.

In addition, the results of this study have been presented at: Poster at High-Speed Research Program / Atmospheric Effects of Stratospheric Aircraft (HSRP / AESA) annual review meeting at Virginia Beach in June 1993; poster at Ames DDF session and Dryden in November 1993; poster at AGU annual meeting in San Francisco in December 1993; poster at 3rd Circumpolar Symposium on Remote Sensing of Arctic Environments in Fairbanks, Alaska, in May 1994; and a presentation at Ames Birds of a Feather Image Analysis Group in August 1994.

References

Burroughs, W. J.: The Development of Satellite Meteorology, chapter 3, Watching the World's Weather. Cambridge Univ. Press, 1991.

Ebert, E. E.: A Pattern Recognition Technique for Distinguishing Surface and Cloud Types in the Polar Regions. J. Climate Appl. Meteorol., vol. 26, 1987a, pp. 1412–1427.

Ebert, E. E.: Classification and Analysis of Surface and Clouds at High Latitudes from AVHRR Multispectral Satellite Data. Ph.D. thesis, University of Wisconsin-Madison, 1987b.

Ebert, E. E.: Analysis of Polar Clouds from Satellite Imagery Using Pattern Recognition and a Statistical Cloud Analysis Scheme. J. Appl. Meteorol., vol. 28, 1989, pp. 382–399.

Hamill, P.; and Toon, O. B.: Polar Stratospheric Clouds and the Ozone Hole. Physics Today, vol. 44, no. 12, 1991, pp. 34–42.

Key, J.: Cloud Cover Analysis with Arctic Advanced Very High Resolution Radiometer Data: 2. Classification with Spectral and Textural Measures. J. Geophys. Res., vol. 95, 1990, pp. 7661–7675.

McCormick, M. P.; Steele, H. M.; Hamill, P.; Chu, W. P.; and Swissler, T. J.: Polar Stratospheric Cloud Sightings by SAM II. J. Atmos. Sci., vol. 39, 1982, pp. 1387–1397.

Solomon, S.; Garcia, R. R.; Rowland, F. S.; and Wuebbles, D. J.: On the Depletion of Antarctic Ozone. Nature, vol. 321, 1986, pp. 755–758.

Turco, R. P.; Toon, O. B.; and Hamill, P.: Heterogeneous Physiochemistry of the Polar Ozone Hole. J. Geophys. Res., vol. 94, 1989, pp. 16,493–16,510.

Welch, R. M.; Sengupta, S. K.; Goroch, A. K.; Rabindra, P.; Rangaraj, N.; and Navar, M. S.: Polar Cloud and Surface Classification Using AVHRR Imagery: An Intercomparison of Methods. J. Appl. Meteor., vol. 31, 1992, pp. 405–420.

Yamanouchi, T.; Suzuki, K.; and Kawaguchi, S.: Detection of Clouds in Antarctic from Infrared Multispectral Data of AVHRR. J. Meteorol. Soc. Japan, vol. 65, 1987, pp. 949–961.

Keywords

Polar stratospheric clouds, AVHRR satellite imagery, Remote sensing and image analysis

Ablating Surface Heat Transfer Estimation for Flight Application

Investigator(s)
Greg Noffz and Mike Bowman,
Dryden Flight Research Center,
Edwards, CA 93523-0273

Objectives of the study

Flight vehicles can be instrumented with subsurface thermocouples such that inverse analysis procedures can yield useful estimates of surface heat transfer. If the vehicle has an ablating heat shield, however, temperature time histories from subsurface thermocouples no longer provide enough information to estimate heat flux at the surface. This situation arises because the problem geometry is changing and thermal energy is leaving the surface with the ablation products. An ablator recession rate is now required to estimate heat transfer to the surface.

This research effort has concentrated on developing a capacitive gage concept in which the ablator has a dielectric effect on the capacitor's fringe region. Relying on a capacitor's fring region enables the gage to be flush mounted in the vehicle's permanent structure and not intrude into the ablative heat shield applied over it. Our goal is to develop this concept into a gage(s) capable of measuring the recession of low temperature ablators that are applied in thin (0.020– 0.060 in.) layers.

The work has been concentrated in two main thrusts. First, candidate gages were fabricated and tested with each successive generation becoming more sophisticated in its packaging. Second, different gage geometries were modeled using finite elements.

Progress and results

A method of measuring the small changes in capacitance, which involves making the gage part of a series resistive-inductive-capacitance (RLC) "load" at the end of a waveguide, has been tested. Radio frequency (RF) energy is sent to the RLC circuit via the waveguide from a signal generator. If the load is excited at its resonant frequency, all the energy from the source is dissipated in the load's resistance. If the load's resonant frequency now changes (say, due to a change in capacitance), some of the RF energy will be reflected back toward the source. This reflected energy is detected by a reflection coefficient bridge (RCB), which outputs a dc signal proportional to the impedance mismatch at the load.

The gage geometries were produced from circuit board material using common etching techniques. The inductor and resistor, which together with the gage form the RLC termination, were attached to the backside of the circuit board. Preliminary tests were performed with this arrangement but the need for a shielded, mechanically stable termination was obvious. This led to the development of the second generation packaging system shown in figure 1. The gage, etched from circuit board material as before, has a resistor and toroidal inductor soldered to its backside. A Delrin chassis supports this assembly and everything is surrounded by a metal casing. The RLC termination is connected to a coaxial cable through a modified male bayonet navy connector (BNC). The entire assembly is potted with room temperature vulcanizing (RTV). The casing is electrically connected to the shield side of the coaxial cable. As hoped for, only the face of the gage is sensitive to its surroundings.

Various gage geometries were modeled using a commercially available finite element code. The models are two-dimensional and intended to illustrate the effect of conductor width and spacing on gage sensitivity. The printed circuit (PC) board and uncharged "ground plane" are included. The infinite domain of the physical problem is simulated with the finite domain of the model with the use of absorbing boundary conditions. Elements above the conductors can be assigned the permittivity either of ablator or of air. Ablator thickness of 0.0, 0.010, 0.020, 0.030, and 0.050 in. are simulated for each gage geometry. Figure 2 shows the results from two gage geometries, one with a conductor width of 0.005 in. and gap width of 0.020 in. (5.20) and one with a conductor width of 0.010 in. and gap width of 0.020 in. (10.20). As expected, the largest change in gage capacitance takes place when the last 0.010 in. of ablator is removed. In these two cases, varying ablator thickness above 0.030 in. does not change gage capacitance much, whereas in the intermediate range (0.010 in.–0.030 in.) the 10.20 geometry is more sensitive. Generally, the geometries with wider conductor widths and gaps tended to be more sensitive at thicker ablator thicknesses than those geometries with thinner conductor widths and gaps. This was also observed in lab tests.

Twenty second generation gages with thirteen different sensing element geometries have been lab tested using the waveguide/RCB arrangement. Delrin shims of various thicknesses were used to simulate the

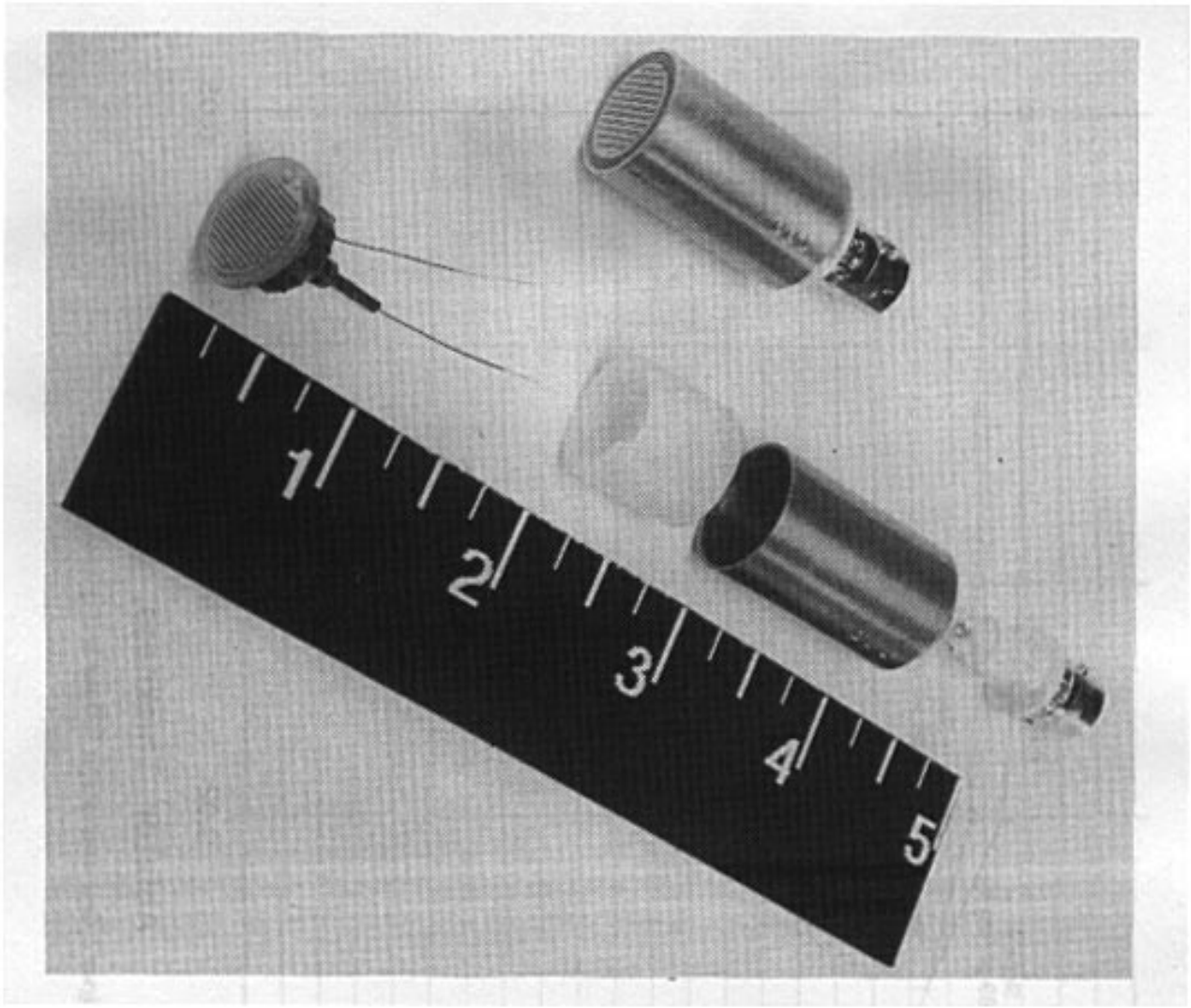


Figure 1. Second generation packaging system.

ablator. Although manufacturing problems (warping and tapering) with the shims have prevented us from obtaining true "Delrin calibrations" for the candidate gages, nevertheless the same trends evident in the finite element modeling were present in the test data. One of the better examples (i.e., wider conductor widths and gaps) is shown in figure 3. RCB output versus Delrin shim thickness is shown for two gages, both with conductor and gap widths of 0.040 in. (1 mm). Gage sensitivity drops off for shims thicker than about 1.5 mm. The RCB arrangement gives a large percentage change in mV output for the range of interest and is insensitive to cable / hardware arrangement and local RF energy.

Tests with a commercially available ablator were conducted using the test panel shown in figure 4. The gages were installed in the panel and the ablator applied over them. Ablator thickness was measured with a dial indicator. This test pointed out the need to coat the gage face to prevent the ablator from entering the region directly between the "plates" of the capacitive gage and overloading the RCB. This problem does not occur with the rigid shims. Qualitative tests of the gage's sensitivity to temperature gave encouraging results with regards to the gage components and output, but the present configuration uses materials such as Delrin, circuit board material, and RTV, which tend to expand, thus pushing the gage face slightly out of the metal casing. The above tests illustrate the need for the next gage configuration: metallic gage patterns deposited in very thin layers (tens of microns) on a high temperature ceramic.

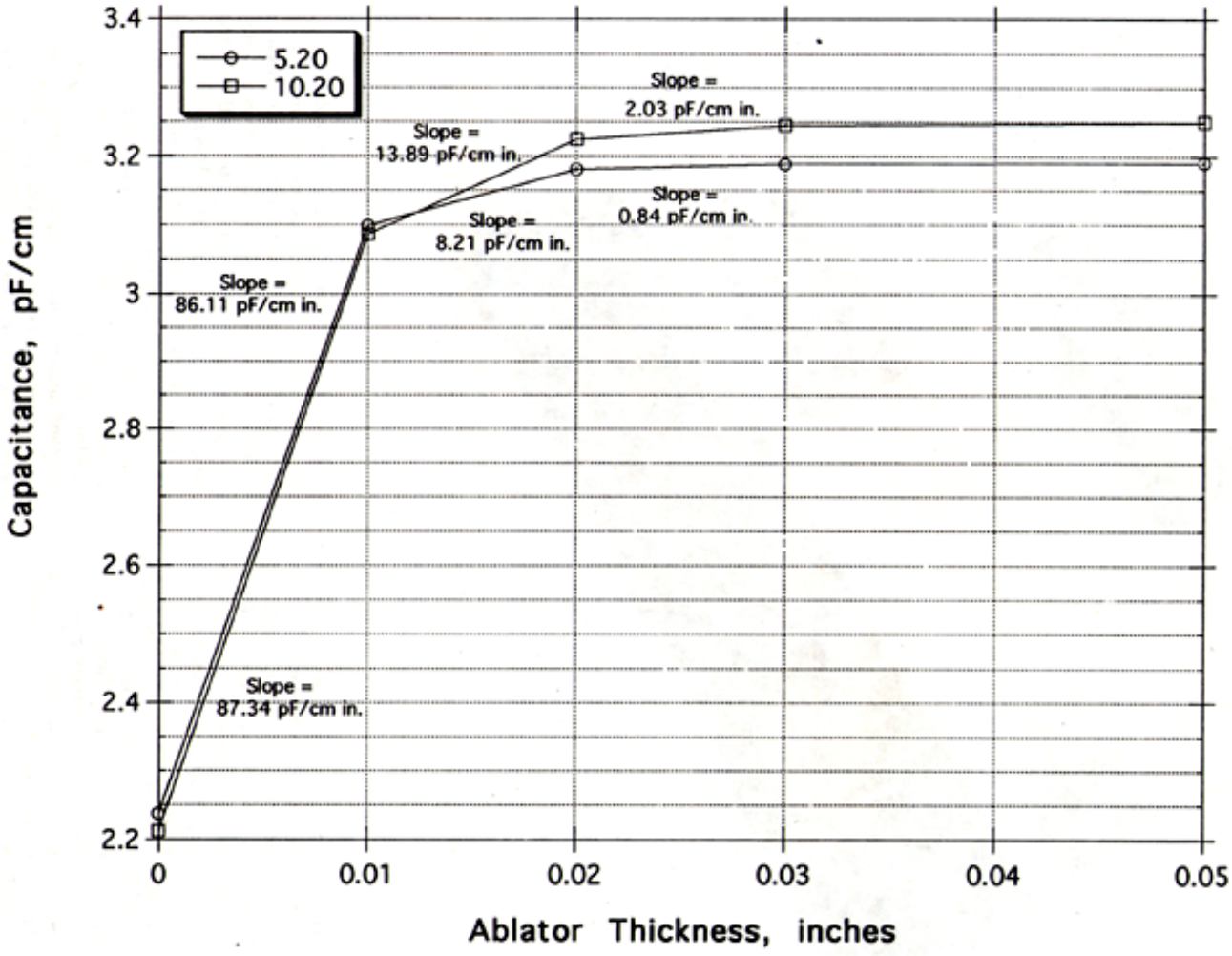


Figure 2. Gage sensitivity for 5.20 and 10.20 geometries.

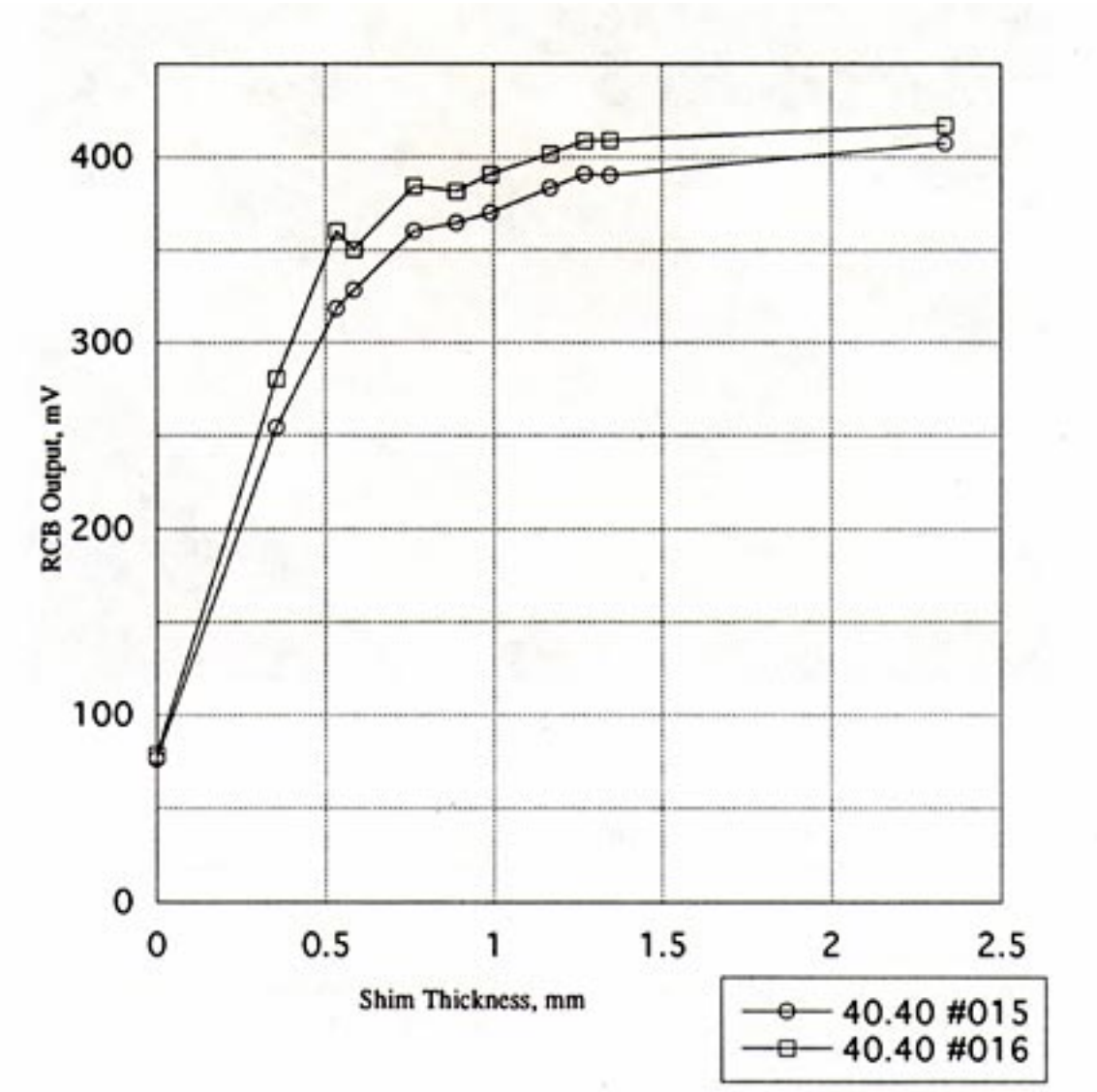


Figure 3. Shim test results: RCB output for gage geometry 40.40 (gages 015 and 016).

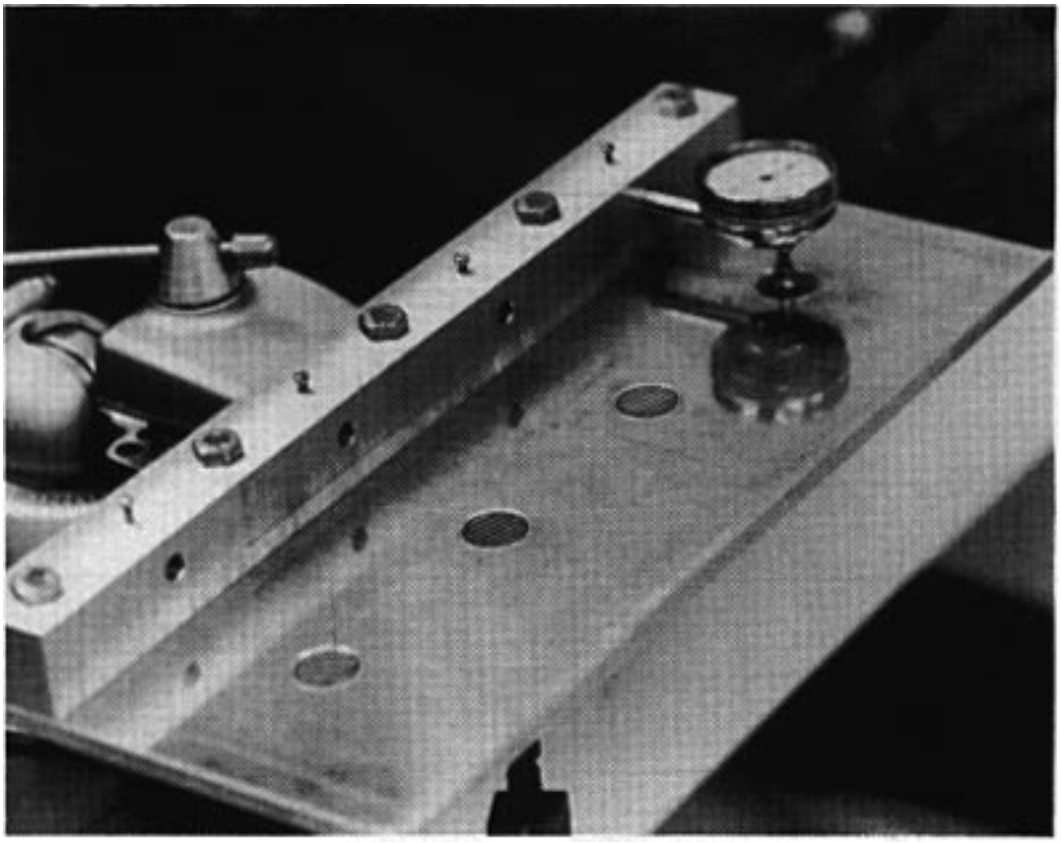


Figure 4. Test panel.

A multiplexing system incorporating an RF switch that will allow four gages to be operated with a single signal generator and RCB is being developed.

Significance of the results

Finite element analysis confirms some of the observations made during lab tests and a third generation gage geometry is being produced, incorporating lessons learned. The packaging system developed provides mechanical stability and shielding, but is not ready for high temperature tests. Results so far indicate that this gage concept has the ability to measure thickness changes in the range and to the resolution equired. Hardware power and size requirements do not exceed what would be available on a flight vehicle. Additional applications possibly include measuring the sublimation rate of surface flow-vis chemicals like naphthalene and wing ice detection.

Publications resulting from study

Noffz, Gregory: Development of a Capacitive Gage for Measuring the Recession of a Thin-Layered Ablator. Master's Thesis, University of California at Los Angeles, 1994.

Keywords

Ablation measurement, Thin film measurement

Crew Decision Making in Aerospace Environments: A Taxonomy of Decision Structures

Investigator(s)
Judith Orasanu, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Ute Fischer, Kimberly Jobe, and Michael Wich,
San Jose State University Foundation,
San Jose, CA 95192

Objectives of the study

Of fatal air transport accidents between 1983 and 1987, 47 percent involved failures of crew decision making, planning, or communication (National Transportation Safety Board (NTSB), 1991). Scientific research has not provided an adequate basis for training or aiding crews to make decisions in complex dynamic environments such as aviation or space. Before we can hope to improve the safety of aerospace decision making, it is essential to understand the nature of decision tasks crews actually face and how they respond to them. The objectives of this project are to:

- Develop a taxonomy of the kinds of decisions crews face in aerospace environments
- Determine the cognitive demands posed by various problem conditions
- Identify vulnerabilities and types of errors crews are likely to make
- Describe effective decision making strategies

Progress and results

The first year of this project involved three major tasks: development of a taxonomy of decision types, characterization of decision errors, and identification of effective decision strategies. Building on this effort, three integrated activities were undertaken in the second year.

- A generic process model of decision making in dynamic environments was developed.
- The dimensions that distinguish decision types were validated through a sorting study conducted with professional pilots from two airlines.
- Effective decision strategies were verified in a full-mission simulator study that also examined the effects of automation on crew performance.

These efforts have yielded the following products and conclusions:

1. All decisions in dynamic situations involve two general processes: situation assessment and response selection. Situation assessment involves defining the nature of the problem, the levels of risk inherent in the situation, and the amount of time that is available for dealing with the problem. If the nature of the problem is not clear, diagnostic efforts may be needed, time permitting. Response selection means choosing a course of action, a process that may vary depending on whether responses are readily available as rules, whether several options must be evaluated, or whether one or more options must be created where none previously existed. The amount of work that must be done to make a decision will depend on how unambiguous the cues are that define the problem and what kind of response options are present in the situation.

2. The notion that situation ambiguity and response availability determine the amount and kind of work demanded and that time pressure and risk levels are multipliers was developed in a bottom-up fashion, through analysis of crew performance in response to various decision situations. To validate these dimensions, a sorting study was conducted with professional pilots from two different airlines that fly in very different weather and terrain conditions. Individual pilots were given brief written flight problem scenarios (taken from our Aviation Safety Reporting System (ASRS) decision event database) and asked to sort them into piles that represent similar kinds of decisions they might have to make if they were in those situations. Participants differed in role (captain, first officer, and flight engineer) as well as experience levels. Sorting data were subjected to multidimensional scaling and clustering analyses, done separately for each crew role. These analyses confirmed the dimensions previously identified. However, they also highlighted important differences in perspective associated with cockpit role, as shown in figure 1. Captains, who have the responsibility for making difficult decisions, focused on risk (both immediate and future) as their primary dimension, whereas this factor was not salient in the other crew positions. Time pressure was relevant to all crew positions. First officers and flight engineers are more concerned with the basis of decisions and with the information that would go into a decision, as befits their roles in the cockpit. Similar findings were found in both airline samples, further supporting the validity of the dimensions and establishing their generality despite differences in everyday practical experience.

3. Data collected in a full-mission simulator study were analyzed to determine whether effective crew strategies previously identified were also evident in a different flight scenario. This simulator study was originally designed to assess the effects of cockpit automation on crew coordination, communication, and performance (errors). We examined strategies in four episodes that varied in the types of demands they placed on the crew and the types of decisions required: (a) preparation for a "missed approach" on landing, (b) entry into a nonpublished holding pattern, (c) management of a generator-related system failure, and (d) a decision about whether and where to divert because of bad weather at the original destination. Our analyses confirmed previous findings about effective crew strategies: More effective crews showed higher levels of situation awareness, planning, task completion (e.g., abnormal checklist procedures), and task management (e.g., buying time to make decisions, not being rushed). These held across both levels of automation. Automation affected performance by slowing down crews' understanding of the nonpublished holding pattern and getting established in the hold. Indirect effects were found in management of the system failure, where the automation seemed to distract crews and lower their monitoring of the degrading system and completion of checklists. It may have also distracted crews from more thorough information gathering and systematic reasoning as they made the diversion decision.

4. In addition to the above new findings, a database has been completed of 96 flight incidents from the ASRS that involve crew problem solving or decision making. These have been coded in terms of the precipitating event, phase of flight of the precipitating event, nature of resulting decisions, phase of flight of resulting decisions, taxonomic classification of resulting decisions, and levels of ambiguity and time pressure in the situations. This computerized database can be accessed by individuals seeking certain classes of events for research or training purposes. A user's manual has also been prepared and is undergoing final revisions prior to distribution.

Significance of the results

We are beginning to understand the characteristics of decisions that crews face in dynamic complex environments, the features that make problems difficult, and crews' responses to those situations. This research is already serving as the foundation for crew training in decision making by several airlines, and it may also be useful in designing systems to support crew decision making in situations that might cause them difficulty and where errors are likely.

Publications resulting from study

Orasanu, J.: Shared Problem Models and Flight Crew Performance. Aviation Psychology in Practice, N. Johnston, N. McDonald, and R. Fuller, eds., Ashgate Publishing, Aldershot, U.K., 1994, pp. 255–285.

Orasanu, J.; Dismukes, K.; and Fischer, U.: Decision Errors in the Cockpit. Proc. of the Human Factors and Ergonomics Society 37th Annual Meeting, Santa Monica, Calif., 1993, pp. 363–367.

Orasanu, J.; and Fischer, U.: Finding Decisions in Natural Environments: Toward a Theory of Situated Decision Making. To appear in Naturalistic Decision Making, C. Zsambok and G. Klein, eds., Lawrence Erlbaum Associates, Hillsdale, N. J.

Orasanu, J.; and Strauch, B.: Temporal Factors in Aviation Decision Making. Proc. of the Human Factors and Ergonomics Society 38th Annual Meeting, Santa Monica, Calif., 1994.

Presentations

Orasanu, J.: Pilot Decision Making: Meeting the Challenge of Abnormal and Emergency Events. Presented at the 22nd Technical Conference on Human Factors in Aviation sponsored by the International Air Transport Association, Montreal, Canada, Oct. 1993.

Orasanu, J.; Dismukes, R. K.; and Fischer, U.: Decision Errors in the Cockpit. Presented in a Panel on Analysis of Error in Complex Decision Making Tasks at the 37th Annual Meeting of the Human Factors and Ergonomics Society, Seattle, Wash., Oct. 1993.

Orasanu, J.: Discussant in a Symposium on Training for Team Coordination and Decision-Making Effectiveness: Theory, Practice, and Research Directions. Presented at the 37th Annual Meeting of the Human Factors and Ergonomics Society, Seattle, Wash., Oct. 1993.

Orasanu, J.: Shared Problem Models and Flight Crew Performance. Presented at the Western European Association for Aviation Psychology Conference, Dublin, Ireland, Mar. 1994.

Orasanu, J.: Decision Making in Action: Meeting the Challenge of Emergency Events. Presented at the Third Offshore Installation Management Conference sponsored by the Robert Gordon University, Aberdeen, Scotland, Apr. 1994.

Orasanu, J.: Group Interaction and Crew Performance. Lecture in course on Life in Space, Stanford University, Palo Alto, Calif., May 1994.

Orasanu, J.: Expert Decision Making in Flight Operations. Presented at the International Civil Aviation Organization (ICAO) Regional Safety Seminar in Amsterdam, The Netherlands, May 1994.

Orasanu, J.; and Fischer, U.: Finding Decisions in Natural Environments. Presented at the Second Conference on Naturalistic Decision Making, Dayton, Ohio, June 1994.

Orasanu, J.: Training for Decision Making in Abnormal and Emergency Events. Presented at the International Civil Aviation Organization (ICAO) Regional Safety Seminar, Addis Ababa, Ethiopia, Oct. 1994.

Orasanu, J.; and Strauch, B.: Temporal Factors in Aviation Decision Making. Presented at the Human Factors and Ergonomics Society meeting, Nashville, Tenn., Oct. 1994.

Invited consultation

Orasanu, J.: Invited by the National Transportation Safety Board to be an Expert Witness on Crew Decision Making for an Accident Investigation, Charlotte, N.C., Sept. 1994.

Orasanu, J.: Methods of Coding Team Decision Making in Complex Dynamic Environments. Presented at a workshop on Team Performance Assessment Techniques (TPAT-1) sponsored by the University of Maryland School of Medicine Trauma Center Research Team, Baltimore, Md., July 1994.

Keywords

Dynamic decision making, Team decision making, Situation assessment

Analysis of Arc-Jet Wind Tunnel Vacuum Ultraviolet (VUV) Experiment

Investigator(s)
Chul Park, Ames Research Center,
Moffett Field, CA 94035-1000
Dikran S. Babikian, Thermosciences Institute,
Ames Research Center

Problem

When an entry vehicle flies through the atmosphere at a super-orbital speed, radiation emitted by the hot shock layer around the vehicle becomes a major source of heating of its heat shield. There is an uncertainty as to what fraction of the radiation energy is contained in the vacuum ultraviolet (VUV) wavelength range below 200 nm. To answer this question, an expriment was carried out in 1992 in one of the 20-MW arc-jet wind tunnels in which radiation falling onto the stagnation point of a 15 cm diameter, flat circular disk was measured spectrally from the VUV to the long wavelength limit of the visible radiation. The data had not been analyzed. One reason was the fact that the state of the gas flow produced in an arc-jet wind tunnel was unknown because of the strong thermochemical nonequilibrium phenomena occurring in the flow. In order to understand the flow conditions, additional spectroscopic measurements, of both the nozzle flow and the shock layer flow from the side-view positions, were also conducted in 1992. The data obtained from these experiments had not been analyzed either.

Objectives of the study

The objectives of the research were: 1) to characterize the flow produced by the arc-jet wind tunnel to enable rational analysis of the VUV radiation data at the stagnation point, and 2) to compare the experimental and calculated spectral radiation intensities. These objectives required: 1) calculation of the characteristics of the arc-heater, 2) calculation of the thermochemical nonequilibrium processes in the nozzle, 3) calculation of the radiation emitted by the nozzle flow and comparison with the side-view experimental data, 4) calculation of the thermochemical nonequilibrium processes in the shock layer over the tested model, 5) calculation of the radiation emitted by the shock layer and comparison with the side-view experimental data, and 6) calculation of radiation incident on the stagnation point and comparison with the experimental data.

Progress and results

As mentioned above, three different sets of spectroscopic data obtained in the 20-MW arc-jet wind tunnel had to be anlyzed: 1) the spectra emitted by the free-stream flow at the nozzle exit, 2) the side-view spectra of the shock-layer radiation emitted in the direction normal to the stagnation streamline of a flat-disk model at various distances from the model surface, and 3) the spectra of the shock-layer radiation incident on the stagnation point of the model. The working gas in all these tests was mostly air containing a small amount of argon.

The computations were made in four steps as follows: 1) the characteristics of the arc-heater were computed using the ARCFLO code; 2) the flow along the centerline of the nozzle of the arc-jet tunnel was calculated using the multitemperature one-dimensional nonequilibrium code NOZNT; 3) the flow over the test model, including the nonequilibrium thermochemical region behind the bow shock wave, was calculated using three different codes; a) a two-temperature one-dimensional nonequilibrium code NONEQ, b) a two-temperature two-dimensional nonequilibrium code 2D2T, and c) a second two-temperature two-dimensional nonequilibrium code NEQ2DBLNTB, which did not include argon and therefore did not simulate the arc-jet flow conditions correctly; however it was used as a check of the 2D2T code; 4) and the spectral intensities were calculated using the radiation code NEQAIR.

These calculations found the following:

1. The mass-averaged enthalpy given by the ARCFLO code is slightly lower than the centerline enthalpy.
2. The NOZNT code solution based on the centerline enthalpy deduced from heat transfer measurements predicts the thermochemical nonequilibrium state in the test section of an arc-jet wind tunnel fairly well.
3. The NOZNT code closely reproduces the measured translational-rotational temperatures and the vibrational temperatures of the arc-jet free stream, and it underpredicts the electron-electronic temperature when compared with the measured values.
4. The NEQAIR code correctly reproduces intensities of most atomic lines but underpredicts those of the continua and molecular bands.
5. The NEQAIR solution based on the flow field calculated using the one-dimensional code NONEQ

reproduces the relative intensity distribution fairly closely.

6. An equilibrium region is found in the shock layer over a 15 cm flat disk model when the stagnation pressures is 0.003 atm or higher. By analyzing the radiation emitted by this equilibrium region, flow enthalpy was determined.

7. The radiation spectra incident on the stagnation point of a model placed in an arc-jet wind tunnel cannot be calculated using the existing computer codes, at least for the tested condition.

8. The VUV component of the radiation incident on the stagnation point is very small.

Significance of the results

We can assess the state of our knowledge about the nature of the flows produced in arc-jet wind tunnels and about the nature of radiation as follows: 1) The nonequilibrium relaxation process in the nozzle of an arc-jet wind tunnel is fairly well known; 2) The nonequilibrium relaxation process behind a shock wave in front of a model placed in an arc-jet wind tunnel is not well known; and 3) an equilibrium region can be produced in the shock layer over a blunt body by appropriately designing the model and operating the facility in a certain way. Enthalpy of the flow can be determined by analyzing the radiation emitted by the shock layer. We are encouraged to pursue development of an instrument to measure enthalpy using the principle discovered by this work. Additionally, the knowledge that the VUV contribution to total radiation is small will settle a controversy that has lasted for over 30 years.

Publications resulting from study

Babikian, D. S.; Craig, R.; Palumbo, G.; and Palmer, G: Measured and Calculated Spectral Radiation from a Blunt Body Shock Layer in an Arc-Jet Wind Tunnel. AIAA Paper 94-0086, Reno, Nev., 1994.

Babikian, D. S.; Gopaul, N. K. J. M.; and Park, C: Measurements and Analysis of Nitric Oxide Radiation in an Arc-Jet Flow. J. Thermophys. and Heat Transfer, vol. 8, no. 4, Oct.–Dec. 1994, pp. 737–743.

Babikian, D. S.; Park, C.; and Raiche, G. A.: Spectroscopic Determination of Enthalpy in an Arc-Jet Wind Tunnel. Presented at 33rd AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nev., 1995.

Bamford, D. J.; O'Keefe, A.; Babikian, D. S.; Stewert, D. A.; and Strawa, A. W.: Characterization of Arc Jet Flows Using Laser-Induced Fluorescence. AIAA Paper 94-0690, Reno, Nev., Jan. 1994.

Park, C.; and Babikian, D. S.: User's Manual for NOZNT and NOX1T, Nozzle in n-Temperature and Nozzle in One Temperature. NASA TN, in review.

Park, C.; and Lee, S. H.: Validation of Three-Temperature Nozzle Flow Code NOZ3T. AIAA Paper 93-2862, Orlando, Fla., June 1993.

Keywords

Arc-jet wind tunnel, Nonequilibrium expanding flows, Radiative heating of blunt body

Three-Dimensional (3-D) Disturbances Generated by Suction Holes for Laminar Flow Control (LFC)

Investigator(s)
Daniel C. Reda, Ames Research Center,
Moffett Field, CA 94035-1000
Jonathan H. Watmuff, MCAT Institute,
Ames Research Center

Objectives of the study

The beneficial effects of suction for delaying transition to turbulence have been known for some time, but only recently has the technology become available to produce large sheets of perforated material for use in aircraft wings at reasonable cost. Flight tests have been conducted recently using porous surfaces containing about 10^9 laser drilled holes of 0.002 inch diameter. The drag reduction obtained by maintaining laminar flow over a substantial portion of the wing surface potentially offers considerable fuel savings. Suction, as a means for laminar flow control, is being seriously considered for production aircraft in the near future.

Even the most sophisticated engineering design tools for predicting the transition location assume that the suction is uniform. In some cases there is evidence to suggest that the discrepancy between the predicted and observed transition location may be due to local three-dimensional (3-D) disturbances that are generated by the discrete holes. It is known that a pair of streamwise vortices are generated by a hole when the suction is strong. Designers of porous surfaces use Goldsmith's Criterion to minimize cross-stream interaction between these vortices. However nothing is known about the streamwise interactions that are likely to be even more important. The objective of this project is to determine the characteristics of disturbances generated by suction holes, whether they decay or amplify with streamwise distance, and whether there are interactions between disturbances generated by different holes, which are aligned, but displaced in the streamwise direction.

Progress and results

A small-scale wind tunnel previously used for turbulent boundary layer studies has been modified for experiments in laminar flow control. The facility incorporates suction through interchangeable porous test surfaces, which are used to stabilize the boundary layer and delay transition to turbulent flow. The thin porous test surfaces are supported by a baffled plenum chamber box, which also acts to gather the flow through the surface into tubes that are routed to a high pressure fan. An elliptic leading edge is attached to the assembly to establish a new laminar boundary layer on the test plate. A slot is used to remove the test section flow below the leading edge. The test section was lengthened and fitted with a new ceiling. Substantial modifications were also made to the 3-D probe traverse.

Transformation of the facility for laminar flow studies has been accomplished with considerable success. The free-stream unsteadiness is 0.08 percent for a unit Reynolds number $Re_x = 1.25 \times 10^6$ m^{-1} (i.e., a nominal free-stream velocity of 18.5 m/s). Intermittent bursting is observed at x = 1.8 m, i.e., $Re_x = 2.25 \times 10^6$, which is very good for an open-return wind tunnel. The layer thickness ranges from 2.5 mm (0.1 inch) to 4.8 mm (0.2 inch) over the measurement range. The conformance of the mean velocity profiles with Blasius profiles is excellent; e.g., the experimental shape factors range from 2.54 to 2.75 compared to the Blasius value of 2.59. The skin friction coefficient C_f estimated from the velocity gradient at the wall follows the Blasius C_f versus Re_x distribution within the experimental uncertainty.

Detailed studies have been made using isolated holes to explore the underlying instability mechanisms. The suction is perturbed harmonically and data are averaged on the basis of the phase of the disturbance. These studies were performed using centerline pressure tap holes in the impervious plate, which has been used to verify the acceptability of the base flow. Experiments concerning suction hole disturbances have consisted of the introduction of a harmonic disturbance at an isolated hole via a speaker attached to a pressure tap line. The streamwise location of the hole corresponds to $Re_x = 1 \times 10^6$, and the nondimensional frequency $F = 40 \times 10^{-6}$ corresponds to most amplified modes at this Reynolds number. Conditions corresponding to strong suction and no suction have been studied. The facility is totally automated under computer control and can be run continuously (24 hours/day) for weeks at a time. Data are collected on a point-by-point basis and multiple probes have been implemented to reduce the experimental run time. An unprecedentedly large quantity of data have been acquired; e.g., two data sets have been obtained on four grids totaling 79,560 data points each. The results are examined using the software tools developed for studying the results of numerical simulations on a

graphics workstation. In both cases (i.e., with and without suction), 3-D contour surfaces in the vicinity of the hole show highly 3-D Tollmein-Schlichting (TS) waves that fan out away from the hole with streamwise distance. With suction, the perturbations on the centerline are much stronger and decay less rapidly, whereas the far field is similar to the case without suction. Downstream the contour surfaces of the bow-shaped TS waves develop spanwise irregularities, which eventually form into clumps. The contours remain smooth when suction is not applied. The spanwise clumping is evidence of a secondary instability that could be associated with suction vortices. The interaction between TS waves generated by two holes, aligned, but displaced in the streamwise direction, indicate that cancellation of TS waves is possible.

Significance of the results

Even without suction, the harmonic point source is challenging for computational fluid dynamics (CFD); e.g., direct numerical simulation (DNS) has been used for streamwise growth. With suction, grid resources are consumed by modeling the flow within the hole, and this makes DNS even more expensive. Designers of porous surfaces use Goldsmith's Criterion to minimize cross-stream interaction. However, nothing is known about the streamwise interactions. Results using two holes, aligned but displaced in the streamwise direction, indicate that partial TS wave cancellation is possible, depending on the hole spacing and disturbance frequency. Using DNS for streamwise interaction studies will be prohibitively expensive if linear superposition cannot be used for the multiple holes. The demonstration of TS wave cancellation from multiple holes is an important result since it implies that an optimal streamwise hole spacing could exist for cancellation of TS waves. The optimum hole spacing would be a function of the flow speed (i.e., TS wavelength).

Publications resulting from study

Watmuff, J. H.: Interaction Between Instabilities Originating from Suction Holes. Presented at the 46th Annual Meeting of the American Physical Society, Albuquerque, N. Mex., Nov. 1993.

Watmuff, J. H.: High-Speed Real-Time Processing of Cross-Wire Data. Accepted for publication in Experimental Thermal and Fluid Science Journal.

Keywords

Suction, TS waves, Instability

Development of a Direct Measurement Transducer for the Oil Wedge Skin-Friction Technique

Investigator(s)
H. Lee Seegmiller, Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

A sensitive capacitance transducer was successfully developed and used to measure a thinning oil wedge on a flat-plate model in the High Reynolds Pilot Channel.

Progress and results

The most significant results from this project are as follows:

A. Demonstrated the ability to measure film thickness in the micron range using a rugged flush mounted transducer.

B. Developed and tested a means of providing remotely controlled oil injection in the line configuration required by the oil wedge technique.

C. A "nonlinear" period of oil wedge thinning was observed at the beginning of a test run using oil of 1000CS viscosity. The initial rapid thinning behavior implies that significant pressure forces are present in addition to the desired shear force. This occurs in an excessively thick oil layer and violates conditions required by various fringe imaging techniques that examine fringe spacing only at the conclusion of a test run. Skin friction values inferred from such "pressure force" contaminated data, could, of course be significantly in error.

D. As a spinoff from the DDF research, a means of detecting ice formation on aircraft and warning the crew was developed. A U. S. patent application was filed on April 26, 1994, entitled "Ice detector and deicing fluid effectiveness monitoring system"

Keywords

Liquid film thickness measurement

Effects of Atomic Oxygen and Nitrogen on Advanced Thermal Protection Materials

Investigator(s)
Susan White, Ames Research Center,
Moffett Field, CA 94035-1000
Joan Pallix and Les Barnes, Thermosciences Institute, Ames Research Center

Objectives of the study

To develop more effective and lighter weight advanced thermal protection materials for spacecraft, it is important to understand how these materials will behave under atmospheric entry heating conditions. One important component of reentry heating involves heterogeneous atom recombination, which can account for a significant fraction of the surface heating rates. In order to predict the full envelope of surface heating rates, atom recombination coefficients are required over surface temperatures ranging from room temperature to ~1,800°C. Experiments performed in the arc-jet facility at the Ames Research Center yield coefficients for surface temperatures in excess of 1,100°C. In order to address the catalytic behavior of thermal protection systems at lower surface temperatures, a versatile laser based diffusion/flow reactor has been developed in collaboration with Richard Copeland at SRI International.

It is well established that diffusion reactor methods are well suited for temperature dependent studies of atom recombination on surfaces of relatively low catalytic activity. A number of diffusion reactor designs have been used to study surface catalysis, most of which use a translating catalytic probe positioned inside the reactor to monitor atom loss due to wall recombination. These techniques have been limited to studies of simple first order surface reactions involving H, O, or N atom recombination. The reactor developed during this funding period is much more versatile in that it applies laser-induced fluorescence (LIF) to study the effects of atom/surface interactions on various catalytic materials. The laser probe method is non-intrusive and will not interfere with the flow field or diffusion in the reactor. The technique is also species selective so that reactant and product concentrations can be monitored directly in most cases of interest to the spacecraft reentry problem. This will allow studies of more complex reactions such as N+O–>NO (there are little data currently available on this surface catalyzed reaction) or CO+O–>CO_2, which is an important issue for the Mars entry problem. The measurements can also be made very reliable, reproducible, and routine with the correct equipment and expertise.

Progress and results

A schematic diagram of the reactor developed during this funding period is shown in figure 1. The technique involves generation of atoms in a microwave discharge. The atoms diffuse down a tube where they can recombine on the walls, which are coated with the catalytic material of interest under steady state conditions. The loss of atoms due to wall recombination is monitored using fluorescence detection. The two-photon fluorescence was obtained by focusing frequency doubled radiation from an excimer-pumped dye laser through the center of the quartz side-arm. Because this is a two-photon process, most of the signal comes from the area near the focus of the excitation laser beam and, therefore, the O-atom concentration can be measured at various positions in the diffusion reactor by either moving the reactor or moving the focus of the laser beam and the detector. A combination of the laser beam geometry and the characteristics of the fluorescence detection system determines the spatial resolution. LIF intensity (I) is measured as a function of distance from the discharge where the atoms are generated and it gives a measure of the atom concentration gradient in the tube. Under the proper experimental conditions, the atom recombination coefficient can be determined from the slope of the line generated from a plot of ln(I) versus X/R where X is the distance from the discharge and R is the diffusion tube radius (fig. 2).

For temperature dependent measurements the active section of the reactor is equipped with a tube furnace, which can heat the system to 1,200°C. The work carried out so far involves room temperature detection of O atom recombination on a quartz catalyst. This simple system was chosen for the initial measurements in order to determine the feasibility of the detection methods and to validate the reactor model used for data analysis. Many of the potential sources of error in measuring atom recombination coefficients by this method have been identified and taken into account in these preliminary investigations. These include scattered light, detector saturation, sample surface cleanliness, reactor design, gas pressure and composition, and selectivity of the laser probe. Through these detailed investigations of experimental variables, an optimized experimental

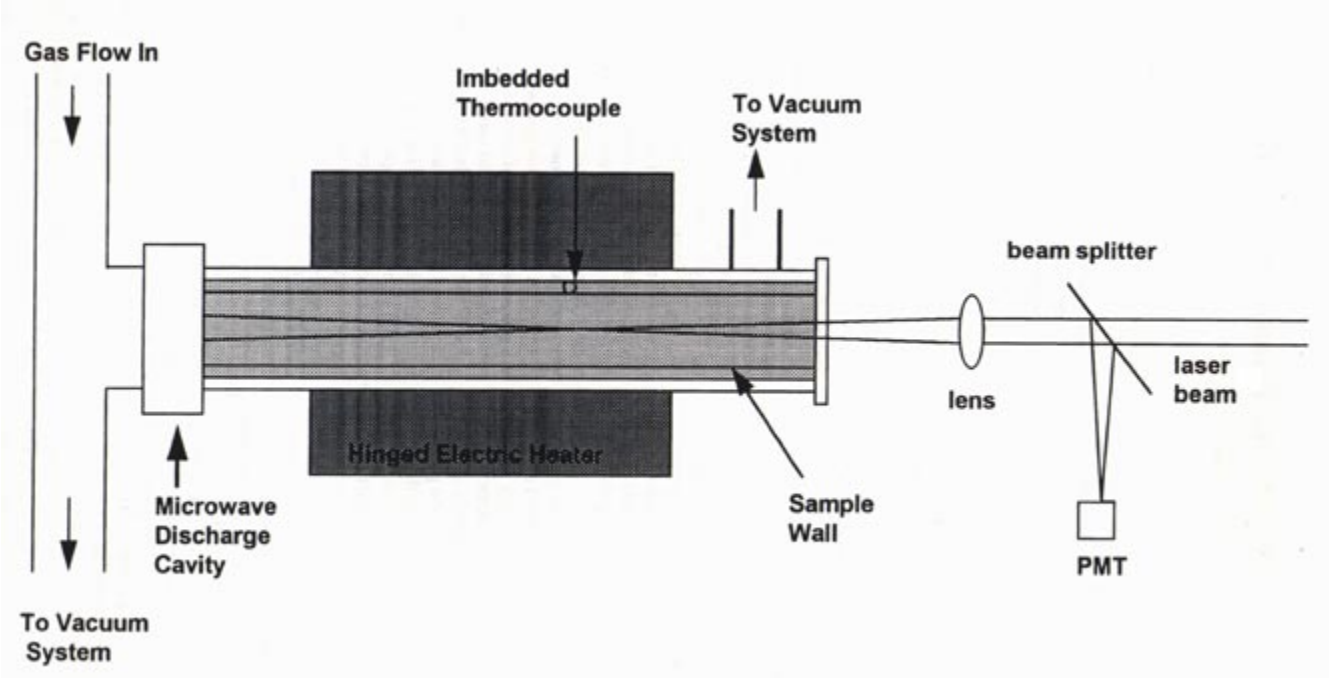


Figure 1. Schematic diagram of diffusion reactor.

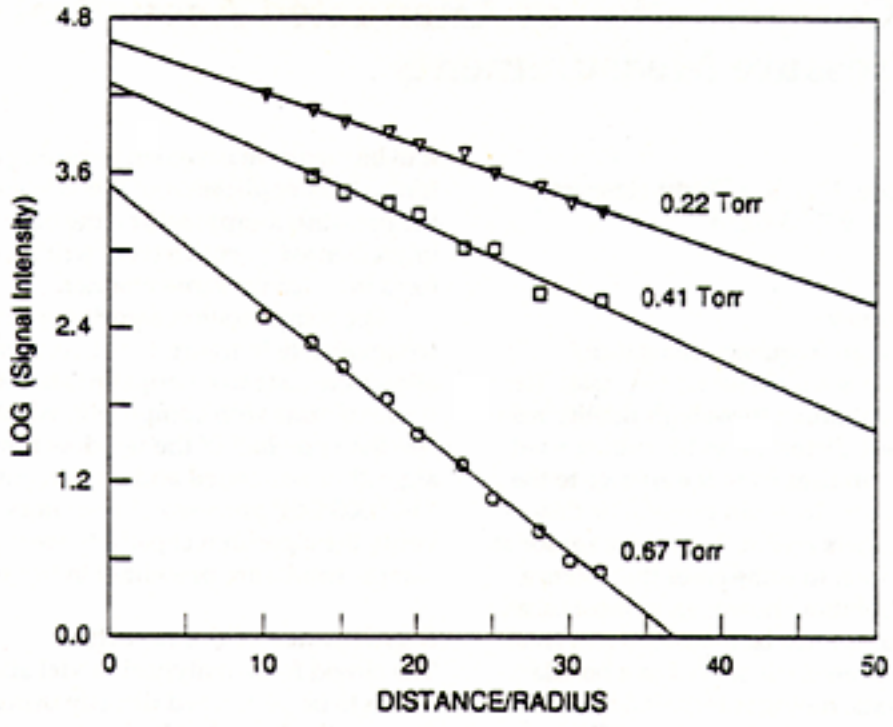


Figure 2. Log (signal intensity) versus the ratio of the distance from the discharge to the radius of the tube for atom loss data obtained at 0.22, 0.41, and 0.67 Torr.

design was possible that will yield more accurate and reliable reaction rate data.

Significance of the results

Through this work, we have established the feasibility of using LIF for detection of atom loss in a diffusion tube to measure surface catalytic activity on a routine basis for all new thermal protection systems (TPS) developed at Ames Research Center. The experimental apparatus is versatile in that it allows fluorescence detection to be used for measuring recombination coefficients as well as for diffusion tube and microwave discharge diagnostics. The results have been invaluable for establishing a design for an improved and more reliable diffusion reactor and model for surface catalysis studies in the thermal protection materials program. Continuation of this program will be supported by the NASA Access to Space Program.

Publications resulting from study

Pallix, J; and Copeland, R.: LIF Detection of O and N Atom Recombination in a Diffusion Reactor. Submitted to the J. Spacecraft and Rockets.

Kneirim, K; Pallix, J.; and Cagliostro, D.: Modeling Considerations for Atom Recombination in a Diffusion Tube. Submitted to the J. Spacecraft and Rockets.

Copeland, R.; and Pallix. J.: Materials Testing Via O and N Atom Detection. Summary Report for Contract No. A40537D, SRI International, Menlo Park, Calif., July 1994.

Copeland, R.; and Pallix. J.: Oxygen Atom Scattering and Recombination Experiments. Summary Report for Contract No. A28698D, SRI International, Menlo Park, Calif., Aug. 1994.

Keywords

Catalysis, Atom recombination, Diffusion reactor

Application of Digital Signal Processing (DSP) to Near Real-Time Compensation of Attenuated Acoustical and Unsteady Pressure Measurements

Investigator(s)
Stephen A. Whitmore, Dryden Flight Research Center, Edwards, CA 93523-0273

Objectives of the study

The measurement of high frequency acoustical/unsteady pressure data is a difficult sensing task. The primary difficulty in obtaining these high fidelity measurements is pneumatic distortion in the tubing used to transmit pressure impulses from the surface to the measurement transducer. To avoid pneumatic distortion, experiment designers seek to mount the sensor at the measurement surface. In some cases this offers a viable measurement solution; however, in most cases, as when many pressures must be measured in a small surface area or when pressure is sensed in a hostile environment, pneumatic tubing is required to transmit pressure from the surface to the transducer. This tubing distorts the pressure impulses and causes a magnitude amplification (resonance) or attenuation and a phase delay (Lamb, 1957; Rayleigh, 1894; Schuder and Binder, 1959; Iberall, 1950; and Berg, 1965).

This research attempts to develop methods for numerical compensation of pressure measurement distortion induced by pneumatic tubing, which cannot be mitigated in the instrumentation design; i.e., the goal is to take the acoustically distorted pressure measurements and perform inverse modeling to compensate for the effects of the distortion using analytical models. The research proposes to apply the compensation methods in real time using digital signal processing (DSP) technology.

Progress and results

Deconvolution algorithms to perform the compensation were developed and verified. An inversion algorithm based on the Wiener filter (Mendel, 1983) has been developed to circumvent this problem. The algorithm basically weights the inverse transfer function as a function of the signal-to-noise power ratio of the measured pressure data.

The actual implementation is performed using a "sliding window" deconvolution in which the Fourier transform has been rewritten to be a recursive implementation. The "sliding window" transform takes the nominal N-point discrete transform and reformulates it to be recursive based on a starting or "seed" transform. After application of the Wiener filter to perform the pressure compensation, the output time series is implemented by recursively writing the inverse transform in much the same manner.

The compensation algorithms are depicted schematically in figure 1. The recursive formulation allows the code to be implemented efficiently in very-near real time with computational latencies always less than one-half of the window time-length. The algorithm was coded and implemented on a TI-C0303 DSP processor. Laboratory experiments to verify the algorithm capability were performed, and sample results are presented in figure 2.

Significance of the results

The closed form analytical model allows the compensation to be performed directly using Fourier transform methods, and it does not require the solution of partial differential equations—a time consuming process that cannot be performed in real time. The development of the filtering algorithm circumvents noise amplification problems, and the "sliding window" algorithm allows the filter to be implemented in real time. The algorithm has already been applied to the reconstruction of the sonic boom signature for the SR-71 from highly attenuated pitot-static pressure measurements.

References

Berg, H.; and Tijdeman, H.: Theoretical and Experimental Results for the Dynamic Response of Pressure Measuring Systems. NLR Report F.238, 1965.

Iberall, A. S.: Attenuation of Oscillatory Pressures in Instrument Lines. National Bureau of Standards Research Paper RP 2115, July 1950.

Lamb, J. P.: The Influence of Geometry Parameters Upon Lag Error in Airborne Pressure Measurement Systems. WADC TR 57-351, Wright-Patterson AFB, Ohio, July 1957.

Mendel, Jerry M.: Optimal Seismic Deconvolution, An Estimated Based Approach. The Academic Press, New York, N.Y., 1983.

Rayleigh, Lord J.: The Theory of Sound. Second ed., Macmillian and Company, London, 1894.

Schuder, C. B.; and Binder, R. C.: The Response of Pneumatic Transmission Lines to Step Inputs. J. Basic Engineering, ASME Transactions, Dec. 1959.

Keywords
Digital signal processing, Deconvolution, Pressure compensation

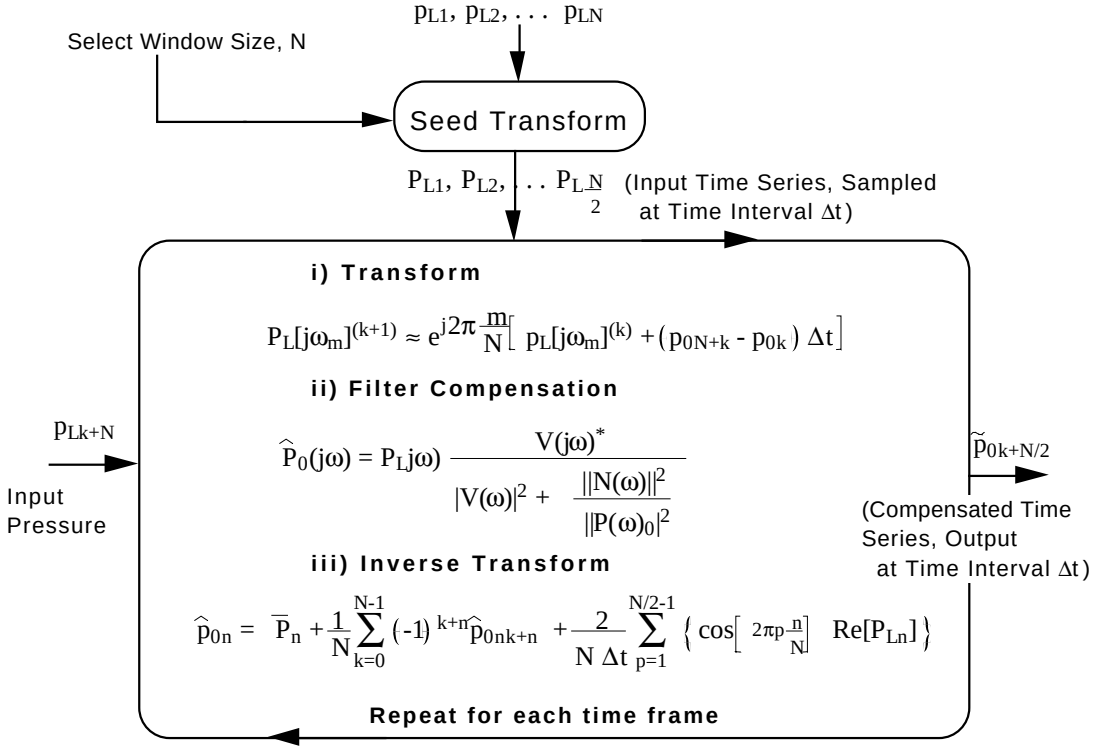


Figure 1. Schematic of compensation algorithm.

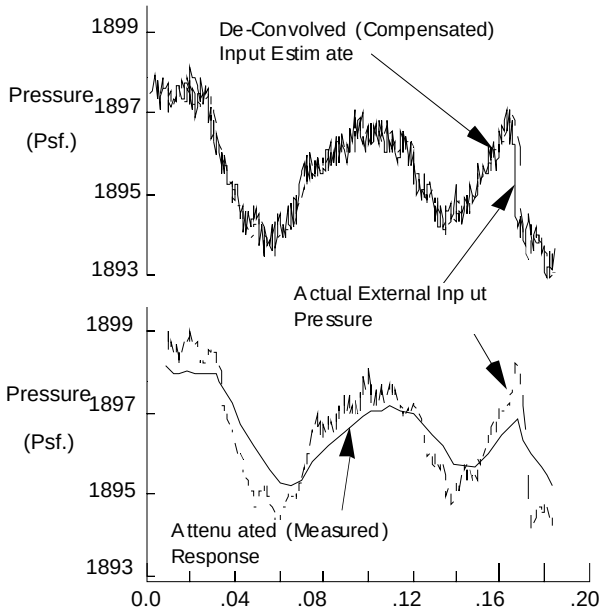


Figure 2. Sample reconstructed pressure time history (real-time algorithm).

Section 2
Ongoing Reports

The Preservation of Organic Matter in Hot Spring Deposits: Developing Search Strategies for a Fossil Record on Mars

Investigator(s)
David F. Blake, Ames Research Center,
Moffett Field, CA 94035-1000
Jack Farmer, SETI Institute,
Ames Research Center

Objectives of the study

The objective of this study is to adapt and apply the techniques of analytical electron microscopy (AEM) to understanding fossilization processes in siliceous thermal spring deposits. AEM is a general term that describes a variety of high spatial resolution analytical techniques, including high resolution transmission electron microscopy (HRTEM), electron diffraction (SAED), energy-dispersive x-ray microanalysis (EDX) and electron energy loss spectroscopy (EELS). In properly prepared samples, it is possible to perform quantitative elemental analyses at the 10–20 nanometer (nm) level, to record structural (electron diffraction) information from <10 nm areas, and to image features of interest with sub-nm resolution. With these new analytical tools, we have been studying the processes by which biological information is incorporated into the fossil record of thermal springs. This is important because thermal springs are regarded to be important environments for early evolution of life on Earth and possibly also on Mars. Although there are good reasons to suspect that the earliest organisms lived at high temperatures, we have not yet discovered thermal spring deposits in ancient rock sequences on Earth. Progress in finding such deposits has been thwarted by a general lack of information about the sedimentology and fossilization processes in modern thermal springs. Thermal spring deposits have also been given a high priority in exploring for evidence of an ancient biosphere on Mars, and they figure prominently as targets for upcoming surface and sample return missions. A major goal of the research is to develop criteria for the recognition of ancient thermal spring microbiotas on the early Earth and Mars.

Progress and results

Based on the early fossil record on Earth, the best preservation of microorganisms occurs when they are rapidly entombed by fine-grained stable minerals prior to their degradation. The most favorable medium for long-term preservation is fine-grained silica that resists chemical breakdown and is able to retain biological information over long periods of geologic time. Siliceous thermal springs are favored for study because extremely high microbial productivity often occurs in combination with high rates of silica precipitation. Not surprisingly, such deposits are often richly fossiliferous because numerous microorganisms become entombed by silica as spring waters rise to the surface and cool. Understanding how post-burial processes, broadly referred to as diagenesis, affects the fossil information in siliceous sediments is basic to interpreting their paleontology. Thus, much of our research to date has focused on studies of diagenesis and its effect on paleontology in silica-rich sediments (cherts) similar to those found in the early record on Earth.

In obtaining samples for study, we extensively sampled thermal spring outflows at several localities in Yellowstone National Park. Samples were initially studied using standard petrographic and light microscopic techniques. We also prepared biological samples by critical point drying methods for scanning electron microscopy (SEM). AEM provides the opportunity to observe the ultrastructure of the microfossils and map associated elemental distributions at high spatial resolution. Microfossils observed in thin sections were subsampled by microdrilling and prepared for AEM by ion milling. Unfortunately, the work has progressed slower than planned because of long delays in the procurement of an ion milling device, critical for AEM sample preparation. Nevertheless, the work to date has provided important insights into the nature and processes of fossil preservation. We have developed an impressive data base of new information about fossilization processes in thermal springs, combining observations from light microscopy and SEM with more focused observations using AEM. This work is being organized into a compendium of microchemical, microstructural, and paleontological observations that will be used to interpret ancient thermal spring deposits. For example, we just completed an initial description of 350-million-year-old thermal spring deposits we discovered last summer in NE Queensland, Australia. Next year we plan to extend our search for ancient deposits to Archean-aged (~3.5 billion years old) rock sequences in Australia and will apply similar techniques to

search for high temperature microorganisms to some of the oldest rocks on Earth.

Publications resulting from study

Farmer, J. D.; and Des Marais, D. J.: Biological Versus Inorganic Processes in Stromatolite Morphogenesis: Observations from Mineralizing Systems. In Microbial Mats: Structure, Development and Environmental Significance, L. J. Stal and P. Caumette, eds., NATO ASI Series in Ecological Sciences, Springer Verlag, 1994.

Farmer, J. D.; Des Marais, D. J.; Blake, D. F.; Walter, M. R.; and Hinman, N. W.: Paleobiology, Mineralogy, and Geochemistry of Modern and Ancient Thermal Spring Deposits and Their Recognition on Early Earth and Mars. Fifth Symposium on Chemical Evolution and the Origin of Life, and Workshop on Mars Exobiology Science Strategy, NASA Ames Research Center, April 25–29, 1994.

Farmer, J. D.; and Des Marais, D. J.: Exopaleontology and the Search for a Fossil Record on Mars. Lunar Planetary Science, vol. 25, 1994, pp. 367–368.

Roles of Biology, Sedimentation, and Diagenesis in Determining Stromatolite Microstructure. Harvard Stromatolite Workshop, Botanical Museum, Harvard University, Cambridge, Mass., Oct. 18–21, 1993.

Farmer, Jack D.: High Resolution Transmission Electron Microscopy. Sponsored by the Mineralogical Soc. of America, Miami, Ohio, Oct. 1992.

NASA Ames Space Science Division, Contractor Recognition Award to Jack D. Farmer, 1994.

NASA Ames Space Science Division, Contractor Recognition Award to Jack D. Farmer, 1993.

Keywords

Mars exobiology, Hot spring sinter, Silification

Isotopic Analysis of Meteoritic Organosulfur and Organophosphorous Compounds

Investigator(s)
Sherwood Chang, Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
George Cooper, National Research Council Postdoctoral Associate, Ames Research Center

Objectives of the study

The hypothesis of the proposed research is that the organic sulfonic and phosphonic acids newly discovered in Murchison meteorite are of interstellar origin. To test this hypothesis, we measure the sulfur (36S / 33S / 32S), carbon (13C / 12C) and hydrogen (D / H) isotope ratios as appropriate for individual (methyl, ethyl, isopropyl, and n-propyl) sulfonic and phosphonic acids extracted from Murchison meteorite. The observation of isotopic ratios that are anomalous with respect to bulk meteoritic or other known solar system values will be indicative of presolar origins. The observation of such anomalies would demonstrate that all the main elements used by life on Earth originated, at least in part, in the interstellar cloud of gas and dust that spawned the solar system. These analyses are especially interesting since no individual organic compounds have ever been studied for their sulfur isotopic compositions, let alone in combination with their C- and H-isotopc compositions.

Progress and results

In the first year of funding, an ion chromatograph was purchased and placed in routine operation for isolation and purification of target compounds. High vacuum sample analysis lines were constructed to convert isolated compounds into gaseous species suitable for analysis by stable isotope ratio mass spectrometry.

We have demonstrated an ion chromatography protocol for a sample-efficient separation, first of bulk organic phosphonates from sulfonates, and then of individual sulfonates from each other with complete or near complete baseline resolution. This separation allows isotopic measurements for C, H, and S on individual compounds. These analytical procedures were also shown not to perturb the natural isotope ratio of carbon. A preliminary set of analyses of individual sulfonic acids (methyl, ethyl, isopropyl, and n-propyl) has been completed.

Significance of the results

Our first set of results show carbon isotope ratios distinct from terrestrial, but well within the range of other meteoritic organic compounds. Apparently, the carbon in these sulfonic acids is not anomalous. A monotonic decrease in the 13C / 12C ratio with increasing carbon number, however, suggests a synthesis of larger compounds by stepwise reaction from one-carbon precursors. This result agrees with earlier results we obtained with meteoritic carboxylic acids.

Apparently, distinctively anomalous isotope ratios must be sought in the hydrogen and sulfur in the sulfonic acids and, presumably, in the hydrogen of the phosphonic acids. We are poised to accomplish these additional measurements in the second year of research.

Keywords

Meteorites, Organic compounds, Stable isotopes

Robust Nonlinear Control and Guidance System Design Methods

Investigator(s)
Victor H. L. Cheng, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Chima E. Njaka, Ames Research Center
P. K. Menon, Santa Clara University,
Santa Clara, CA 95053

Objectives of the study

The overall objective of this research is to investigate methods for designing nonlinear control systems that can tolerate substantial variations in the plant parameters without becoming unstable or suffering significant degradation in performance, for the automation of aircraft guidance and control. The detailed objectives are:

- To understand the source of performance degradation due to uncertainties in a realistic aircraft model.
- To develop design methods for controllers that can provide robust performance under some bounded nonlinear system uncertainties.
- To evaluate the design techniques to verify the improvement in robustness over existing controller designs.

Progress and results

Two approaches were proposed for the investigation of design methodologies for robust nonlinear controllers for automation of aircraft guidance and control systems. A helicopter control problem has been selected as the application to evaluate these approaches because of the criticality of robust performance and stability of helicopters in ground-hugging nap-of-the-Earth (NOE) flight. During the first year of this two-year effort, a baseline controller for attitude control of the UH-60A Black Hawk Helicopter has been designed based on the GenHel simulation model. This baseline controller involves a nonlinear inverse of the helicopter's rotational dynamics, which is modeled based on linearization of the force and moment aerodynamics over the flight envelope of interest. The nonlinear-inverse controller constitutes part of the robust controller to be designed with the first approach. Preliminary analysis of this nonlinear-inverse controller is complete. Work has already started on the second approach, for which a force/moment generation software model has been developed to serve as an integral part of a robust nonlinear controller.

Significance of the results

Analysis of the nonlinear-inverse controller already suggests that, because of the approximation introduced by linearization of the force and moment aerodynamics, the overall closed-loop system does not behave entirely like a linear time-variant system, as it should. Hence model uncertainty is inherent in this baseline closed-loop system. This system would serve as a good starting point to evaluate the full robust controller, which, if successful, should provide improved performance under such model uncertainty.

Publications resulting from study

Njaka, C. E.; Menon, P. K.; and Cheng, V. H. L.: Towards an Advanced Nonlinear Rotorcraft Flight Control System Design. Paper presented at the 13th AIAA/IEEE Digital Avionics Systems Conference, Phoenix, Ariz., Oct. 30–Nov. 3, 1994.

Keywords

Guidance and control, Nonlinear controller, Robust controller

Study of Efficiency Gain and Emission Reduction in a Pulse Combustor Design for Jet Engines

Investigator(s)
G. S. Deiwert, Ames Research Center,
Moffett Field, CA 94305-1000
J-L. Cambier and Henry G. Adelman,
Thermosciences Institute, Palo Alto, CA 94303

Objectives of the study

To study the effects of pulsed combustion on both combustion efficiency and NOx formation for gas turbines. The first objectives are to develop a computational model of the pulse combustor and to analyse the fundamental processes of pulsed combustion and their dependence on various characteristic time scales. Once this is established, the study will focus on the tuning of the combustor parameters for minimization of NOx production and / or maximization of efficiency.

Progress and results

A one-dimensional version of a combustion code has been used for the simulations of the pulsed combustor. The code is presently being modified for more generalized boundary conditions. A reduced chemical scheme of propane-air combustion has been also devised, such that the kinetics of NOx formation can be still modeled, while the unimportant details of the combustion mechanism are ignored, leading to dramatic savings in computational cost. The code has been implemented also on a Silicon Graphics, Inc. (SGI) workstation, with a graphics interface for real-time visualization of the flow field.

A generic pulse combustor operating at atmospheric pressure is presently being studied. The first group of simulations compared the steady flow results with those where acoustic waves are artificially generated. It was verified that the acoustic waves could propagate accurately with the second order scheme used. A second group of simulations was then performed, where the pulsations were forced by imposing a sinusoidal variation of the global combustion rate. This is intended to model the periodic acceleration and deceleration of a turbulent flame within the combustor chamber. It was found that the pulsations could be amplified for certain frequencies, with an apparent resonance around 200 Hz. The oscillations were also found to go through sequences of mode doubling as the frequency was decreased. It was found also that, by abruptly stopping the forcing mechanism, the pulsations were seen to rapidly disappear, even for the resonant case, suggesting the existence of a strong damping mechanism. This may be associated with the geometry of the combustor, and it will be systematically investigated soon. The NOx production was also seen to oscillate, as can be seen, for example, in figure 1, but with only small effects on the cycle-averaged values. The oscillations were also observed to be strongly dependent on the nature of the boundary condition imposed near the combustor entrance. The presence of a flapper valve, for example, by limiting the rate of fuel / air injection into the burner, leads to much smaller amplitudes of pressure and velocity oscillations.

Significance of the results

The current preliminary results indicate that, with appropriate conditions, strong pulsations can be generated in the combustor. The influence of the type of boundary conditions is very important and will be further studied. The code will be further developed for more complex configurations (multiple injection ports, recirculations). It is clear that the fundamental physics

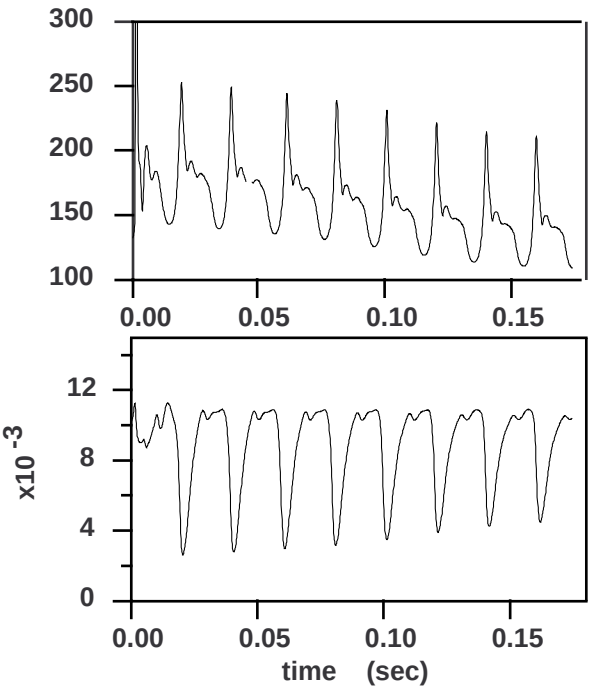


Figure 1. Velocity and NOx fluctuations (at end of pipe), for the case of forced pulsations at 50 Hz. The dips in NOx are in phase with the velocity peaks in the pipe.

of the pulse combustion can be quite complex, and systematic parametric analyses must be performed with great care.

Keywords
Propulsion, Detonation

Biotechnological Applications of Reuseable Surface Insulation

Investigator(s)
Howard E. Goldstein and Daniel B. Leiser,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The objective of this study is to modify the insulation used on the Space Shuttle to produce optimized functionally gradient ceramics for use in animal implantation experiments by W. Casey Fox of BioMedical Enterprises, Inc., San Antonio, Texas, and Thomas B. Aufdemorte of the University of Texas, Austin, Texas. The material properties that are desired in this system are a compressive strength of 5 to 50 megaPascals (MPa), and a variable pore size of 50 to 500 microns (μ) that transitions to a pore size of 0.1 to 5 μ at the soft tissue interface. The processing methods for the materials will be developed and the chemistry studied.

Progress and results

W. Casey Fox and Thomas B. Aufdemorte have successfully implanted off-the-shelf reuseable surface insulations (RSI) materials into monkeys. This work has shown that RSI bone implants can work and they are very biocompatible. However, little bone ingrowth was observed in the "initial" materials, and the material properties of the RSI ceramic fiber system needed improvement to be successful in a wide variety of applications. One of the properties needing modification was the pore size of the material, and therefore, a determination of the appropriate size required was needed. As a result, samples of different RSI with three sizes of holes (~160μ, ~240μ, and ~375μ) were prepared for the next animal implant experiment of Aufdemorte and Fox to determine if bone ingrowth is faster in one size hole versus another or if it is inhibited in any hole. Several modifications of standard RSI have also been evaluated in an effort to provide an improved bone implant material. These modifications include 1) using different composition RSI (i.e., fibrous refractory composite insulation (FRCI)-40 and alumina enhanced thermal barrier (AETB)-40) as the insulation precursor, 2) sintering the insulation at higher temperatures (i.e., 2,600°F) for extended periods of time, and 3) using different pretreatments of the insulation. Thus far these attempts have been unsuccessful as the pore size was not significantly modified from the off-the-shelf material. Another modification of the material produced by using inert fillers in the insulation during processing was also prepared. Preliminary examination of this material indicates that some modification of the pore size has occurred, but only the animal implantation experiments under way will determine its viability.

Significance of the results

Hundreds of thousands of bone implants have been performed using less than ideal metal and organic materials. In many cases the implants have to be replaced every few years. The ultimate result of this research project might be to produce implants that are as viable as the natural bone. The payoff in terms of ameliorating human suffering is potentially enormous.

Keywords

Bone implant, Reuseable surface insulation, Biocompatibility

A Long-Duration Test Flight of a Super-Pressure Balloon as a Platform for Mars Exploration

Investigator(s)
Robert M. Haberle, G. Scott Hubbard,
Lawrence G. Lemke, and Geoffrey A. Briggs,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
James Cantrell, Utah State University,
Logan, UT 84322-4140

Objectives of the study

Demonstrate that a super-pressure balloon made from Biaxial Nylon 6 can survive for at least one year in the Earth's stratosphere at 120,000 feet, where the pressure and temperature conditions are similar to those expected on Mars.

Progress and results

Prior to committing our DDF funds, there were numerous attempts to launch a nylon super-pressure balloon by the Winzen Corporation (the manufacturer). None of these launches were completely successful. A grant was let to the Space Dynamics Lab (SDL) at Utah State University to study the problem and design a flight test program that would lead to the achievement of our objective. SDL recommended a design change (removal of the center load line) and a series of flight tests that would begin with less ambitious objectives. For the first flight, the objectives were to (1) reach the assigned altitude, (2) pressurize, and (3) survive one day / night transition. This launch occurred on August 30, 1994, and two of the three objectives were met. After inflation, the balloon's cut-down system fired prematurely, separating the payload from the balloon. As a result the balloon ascended to a much higher altitude than planned and ultimately burst. Thus, the third objective was not achieved.

Significance of the results

Visual tracking of the balloon showed that the new design is viable since the balloon reached its design altitude without distortion or twisting (as was the case with the old design). It also showed that the balloon successfully pressurized, and that it ascended at least 20,000 feet beyond its design altitude. This success indicates that the super-pressure margins for this material are much greater than theoretically predicted.

Publications resulting from study

James Cantrell is preparing a final report.

Keywords

Mars, Super-pressure balloon, Biaxial Nylon 6

Intervertebral Disc and Back Pain Studies Using Spinal Traction and Compression during Magnetic Resonance Imaging

Investigator(s)

Alan R. Hargens, Ames Research Center, Moffett Field, CA 94035-1000
Gita Murthy and Donald E. Watenpaugh, University of California at San Diego, Ames Research Center
Jorma Styf, Ames Research Center
Karen J. Hutchinson, University of California at San Diego, Ames Research Center
Douglas F. Schwandt, Bionetics, Inc., Ames Research Center

Other personnel involved

Richard Ballard, University of California at San Diego, Ames Research Center
Klaus Fechner, V.A. Medical Center, Palo Alto, CA 94304-1200
Wenonah Vercoutere and Sue Bowley, Ames Research Center

Objectives of the study

The objectives of the first phase of this research were to study intervertebral disc height and other potentially pain-related variables during simulated microgravity. Astronauts experience height increases of four to seven cm in microgravity. Stretching of nervous, muscular, and ligamentous tissues may be responsible for the back pain associated with existence in microgravity. Axial compression of the spine makes six deg head-down tilt (HDT) an unsuitable model for spinal acclimation to microgravity. However, this axial compression may be counteracted by balanced traction consisting of 10 percent body weight applied to the legs.

Progress and results

Six healthy male subjects underwent three days each of six deg HDT with balanced traction and horizontal bed rest (HBR), with a two week recovery period between treatments. Total body and spine length, ultrasonographic lumbar disc height, back pain, erector spinae intramuscular pressure, peripheral nerve conduction, and maximal ankle joint torque were measured before, during, and after each treatment. Total body and spine (processes of vertebrae L5 – C7) lengths increased significantly more during HDT with balanced traction (22 ± 8 mm and 25 ± 8 mm, respectively) than during HBR (16 ± 4 mm and 14 ± 9 mm, respectively). Back and leg pain were significantly greater during HDT with balanced traction than during HBR. The distance between the lower endplate of L4 and the upper endplate of S1, as measured by ultrasonography, increased significantly in both treatments to the same degree (2.9 ± 1.9 mm, HDT with balanced traction; 3.3 ± 1.5 mm, HBR). Back intramuscular pressure, leg nerve conduction velocity, and maximal ankle joint torque were unaltered with both models.

We have also completed design of the spinal compression harness to be used in the second phase of this study.

Significance of the results

Although neither bed rest treatment increased height to the magnitude observed in microgravity, HDT with balanced traction may be a better model for simulating the body lengthening and back pain experienced in microgravity. Results suggest that microgravity-induced back pain may result from localized effects of loss of spinal curvature; intramuscular pressure elevation and nerve stretching/compression are probably not involved.

The compression harness will allow us to quantify relationships between spinal loading and disc physiology and morphology in the second phase of this project. In the future, the harness will be used clinically to load the spines of recumbent patients during magnetic resonance imaging for diagnosis of back problems.

Publications resulting from study

Styf, J. R.; Kälebo, P.; and Hargens, A. R.: Lumbar Intervertebral Disc Heights as Measured by Sonography. Aviation, Space, and Environmental Medicine, vol. 65, no. 5, 1994, p. A12.

Ballard, R. E.; Styf, J. R.; Watenpaugh, D. E.; Fechner, K.; Haruna, Y.; Kahan, N. J.; and Hargens, A. R.: Head-Down Tilt with Balanced Traction as a Model for Simulating Spinal Acclimation to Microgravity. Presented at the American Society for Gravitational and Space Biology Meeting, San Francisco, Calif., Oct. 19–22, 1994.

Styf, J. R.; Fechner, K.; Ballard, R. E.; Watenpaugh, D. E.; Kahan, N. J.; and Hargens, A. R.: Height Increase, Neuromuscular Function and Back Pain During 6° Head-Down Tilt with Traction. Aviat. Space Environ. Med. In preparation.

Haruna, Y.; Styf, J. R.; Kahan, N.; and Hargens, A. R.: Hoffmann-Reflex is Delayed During 6° Head-Down Tilt with Balanced Traction. In preparation.

Keywords

Microgravity, Ultrasonography, Back pain

Turbulent Boundary Layer Measurements on Transport Wing Wind Tunnel Models

Investigator(s)
Dennis A. Johnson, Ames Research Center,
Moffett Field, CA 94035-1000
Jeffrey D. Brown, Eloret Institute
Sunnyvale, CA 94087

Objectives of the study

The objective is to evaluate candidate laser Doppler velocimeter (LDV) approaches for transport wing boundary-layer measurements.

Progress and results

Measurements of both the streamwise and the cross-flow velocity components are needed to define the viscous boundary layers on transport wing wind tunnel models. Moreover, these measurements must be made very close to the surface of the wind tunnel model since the boundary layers are relatively thin. The extreme gradients in velocity within the boundary layer also place severe demands on spatial resolution. The requirements are further complicated by the need to measure separated flows.

In the current research, LDV approaches that provide better spatial resolution, greater sensitivity to the cross-flow velocity component, and less susceptibility to surface light scattering than previous approaches are being evaluated.

Laser light scattered from the surface of the wing represents the most formidable problem. This scattered light results in additive noise that can overwhelm the weak signals produced by the scattering of laser light from small submicron particles in the airstream. (In LDV, local instantaneous airflow velocities are deduced from the Doppler shift of laser light scattered from airborne particles.)

Through laboratory studies, as part of this DDF project, it has been confirmed that the amount of laser light scattered from the surface of the model can be reduced dramatically by placing inserts that are optically smooth on the wind tunnel model. Several types of insert materials have been examined. One of these is replicated nickel, for which the root mean square (rms) roughnesses can be as small as several hundred angstroms.

It has also been determined that substantial improvements in near-surface measurement performance result as the laser beams are brought into a tighter focus at the point of velocity measurement.

The next step in this research is to perform wind tunnel studies that more accurately simulate the conditions observed in wing testing.

Significance of the results

The laboratory results obtained so far give reason for optimism, but the determination of actual measurement capabilities awaits wind tunnel tests to be performed soon.

Keywords

Boundary layers, Wings, Laser Doppler velocimetry

Flight Measured Wall Pressure Fluctuations Beneath Swept Shock/Boundary Layer Interactions

Investigator(s)
Steven A. Johnson,
Dryden Flight Research Center,
Edwards, CA 93523-0273

The goal of the proposed study is to assess the acoustical loads generated by a swept shock/boundary layer interaction in a flight environment (free of wind tunnel turbulence) and to gain a better understanding of the physical mechanisms involved in their generation. Such an understanding is the first step in any attempt to control or limit acoustic loading on flight vehicles. Also, more fundamentally, the interaction unsteadiness is critical in formulating physically accurate flow models and interpreting existing data.

Obtaining these types of measurements is critical to the development of advanced flight systems such as the high-speed civil transport (HSCT) and other high-speed flight vehicles. Fluctuating pressure loads are especially significant in that they can occur in conjunction with high aerothermal loads, and they can threaten the structural integrity of flight vehicles.

The shock wave/boundary layer interaction is generated by an equilibrium, flat plate turbulent boundary layer interacting with a swept, planar oblique shock wave. The shock wave is generated by an "upright," sharp-leading-edged fin at angle of attack. A schematic of the arrangement is shown in figure 1. Also shown schematically are the fluctuating pressure measurement locations to be used in the experiment. Transducer ports are provided in the flat plate at 2 deg angular separations from 15 deg to 65 deg with respect to the free-stream direction. The flat plate/fin apparatus will be attached to an existing "flight test fixture" and mated to the underside of an F-15B aircraft. The flight test fixture is a specially modified pylon that is mounted vertically on the lower centerline of the F-15B. The F-15B, capable of speeds up to Mach 2.0, will serve as the carrier aircraft for the experiment.

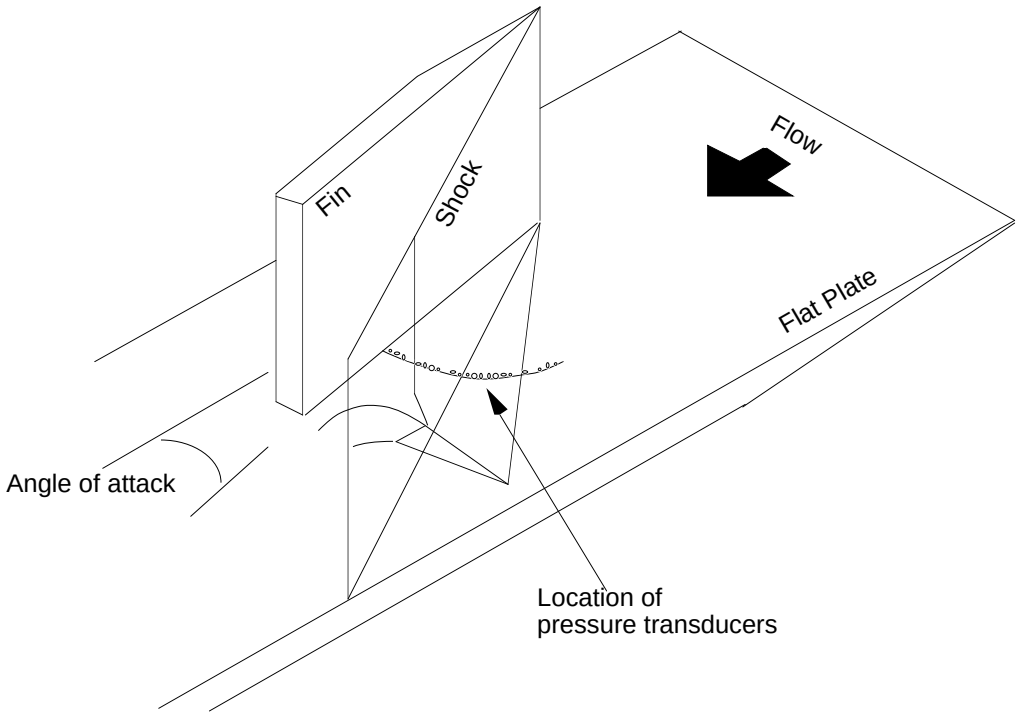


Figure 1. Model schematic showing transducer locations.

The test cases are chosen to span a wide range of interaction strength. Previous investigators have found that important features of swept shock-wave/boundary layer interactions (SWBLIs) scale with the strength of the inviscid shock wave, which can be represented by either the Mach number normal to it or the pressure rise across it. As a result, various fin angles (shock strengths) will be investigated at a free-stream Mach number of 2.0.

Much has been accomplished since funding was awarded. All flight hardware has been designed and fabricated. All instrumentation required for the acquisition of the unsteady pressures has been developed and fabricated. A stand-alone, on-board data acquisition system has been developed that will reside within the flight test fixture and will acquire the high sample rate (100 kHz) pressure data.

In fiscal year 1995, a complete checkout of the integrated system is planned—flight hardware, power supplies, signal conditioning, and data acquisition. After the systems operation is successfully demonstrated, a series of five high-speed flights will occur using the NASA F-15B as the carrier aircraft.

Keywords
Unsteady pressures, Shock/boundary layer interactions, Flight research

Practical Evaluation of a New Method to Reduce Helicopter Rotor Hub Loads

Investigator(s)
Sesi Kottapalli, Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
Judah Milgram and Inderjit Chopra, University of Maryland, College Park, MD 20742

Objectives of the study

The objective of this study was to evaluate a new passive device to reduce helicopter rotor hub loads. This device is called the dynamically tuned blade pitch link.

Progress and results

The research reported here, an outgrowth of the work reported last year, was performed using the analytical rotorcraft code UMARC (University of Maryland Advanced Rotorcraft Code). This finite element code allows for a more sophisticated modeling of a blade configuration under the effect of additional, parametric torsional damping.

Under this grant a modified version of UMARC was created in which it is possible to vary the pitch link damping instead of the blade modal torsional damping that had been previously considered using an earlier, completely different code. In the code that was used earlier, there was no provision to model pitch link damping as a valid parameter. Including pitch link damping instead of the modal torsional damping results in a more practical evaluation since pitch links (with no damping) are an integral part of current production helicopters. Finally, pitch link stiffness has also been included as a parameter and the phrase "dynamically tuned blade pitch link" has been coined to describe the resulting complete concept.

The dynamically tuned blade pitch link is a device in which a rotor blade pitch link (also commonly referred to as a pushrod) is replaced by a spring/damper element. A sample study has been conducted using an articulated rotor blade, the S-76 blade. To summarize, it was found after extensive study that pushrod damping in combination with reduced pushrod stiffness results in significant reductions in 4/rev fixed system hub loads. In this context, figure 1 shows that the longitudinal inplane shear was reduced by 25 percent, the roll moment by approximately

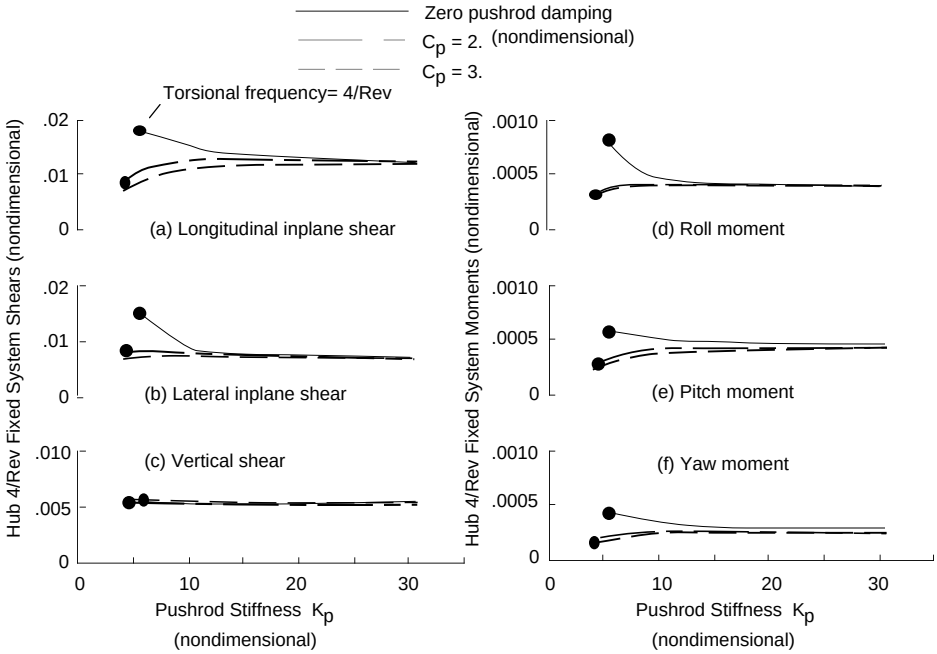


Figure 1. Variations in fixed system hub loads due to parametric changes in pushrod stiffness and damping; advance ratio = 0.38, thrust coefficient divided by solidity = 0.080, shaft angle = 5 deg. Pushrod stiffness and damping nondimensionalized by a reference mass, rotor speed, and blade radius.

20 percent, and the pitch moment by 25 percent. The lateral inplane and vertical shears stayed the same. At the same time, the 1/rev pushrod loads (not shown here) increased by about 50 percent. The design of a dynamically tuned blade pitch link may involve the redesign of a production pushrod in order to accommodate the required stiffness/damping, and any additional fatigue considerations arising from the increased 1/rev loads can be included in this redesign phase. The present reductions in hub loads signify that the dynamically tuned blade pitch link is a promising concept.

The next phase in this study in 1995 involves evaluating this concept for a tilt rotor configuration.

Publications resulting from study

Milgram, Judah; Chopra, Inderjit; and Kottapalli, Sesi: Dynamically Tuned Blade Pitch Links for Vibration Reduction. Presented at the 50th Annual Forum of the American Helicopter Society, Washington, D.C., May 1994.

Keywords

Rotorcraft, Vibration reduction, Pushrods

Computational Fluid Dynamics (CFD) Simulation of Left Ventricular Assist Device (LVAD)

Investigator(s)
Dochan Kwak, Ames Research Center,
Moffett Field, CA 94035-1000
Cetin Kiris, MCAT Institute,
Ames Research Center

Objectives of the study

Develop and apply computational fluid dynamics (CFD) tools to simulate steady and unsteady flows within artificial heart assist devices. This research is designed to provide a tool that can be used to investigate the flow of blood through a ventricular assist device. This unique insight into the internal fluid structures will lead to improved artificial devices capable of sustaining human life.

Progress and results

In 1989, the NASA Johnson Space Center (JSC) began a joint project with the DeBakey Heart Center of the Baylor College of Medicine (BCOM) in Houston, Texas, to develop a new implantable left ventricular assist device (LVAD) prototype system. This LVAD is based on a fast rotating axial pump requiring a minimum number of moving parts. To make it implantable, the device has been made as small as possible, requiring a very high rotational speed. The flow through the baseline design of the LVAD impeller was numerically simulated by solving the incompressible Navier–Stokes equations in a steadily rotating frame of reference. The pseudocompressibility approach and zonal multiblock grids were used in these component analyses. A parametric study was performed to optimize the impeller blade shape and the tip clearance. The ideas from rocket propulsion and medical science were combined to help develop a new implantable LVAD. Using the new computational technology, the researchers in collaboration with the JSC engineering team are investigating new design possibilities by combining a rocket engine inducer with an axial blood pump impeller. The BCOM is currently performing clinical hemolysis testing and animal implantation. The new design is showing a remarkable improvement in performance over earlier blood pump designs.

Significance of the results

The goal of this research was to develop computational tools that could be used by the designers of mechanical heart assist devices, such as the JSC / BCOM LVAD. This computational tool now affords designers with a view of the complicated fluid dynamic processes inside their devices. Because of the nature of the devices, this detailed information cannot be obtained experimentally. The detailed computational look at the fluid flow is very important to the designers; high levels of turbulence can damage the red blood cells, and regions of recirculating flow can lead to blood clots. Thus the ability to predict these phenomena have greatly helped the designers.

In July 1991, the Institute of Medicine estimated that approximately 25,000 to 60,000 patients per year in North America could benefit from an efficient LVAD. Thus improved designs made possible because of the current work could have a significant impact on human health.

Keywords

Computational fluid dynamics, Incompressible flow, Left ventricular assist device (LVAD)

A Study of Atmospheric Sampling by Supersonic Aircraft

Investigator(s)
Stephen R. Langhoff and Henry G. Adelman,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The use of supersonic aircraft with long-range and high-altitude capabilities has been proposed to obtain atmospheric samples to study the depletion of the ozone layer over the polar regions. However, there is a possibility of changes in the composition of samples that have passed through the shock waves generated by the aircraft at supersonic speeds. At these elevated temperatures and pressures, the samples may undergo chemical reactions that would alter their composition dramatically, giving incorrect sampling results. The extent of chemical changes that might occur during supersonic sampling will depend on the speed and altitude of the aircraft and the temperature and pressure history of the sample.

Progress and results

Reacting flow models are being used to determine possible sample chemistry changes due to the increase in temperature and pressure across shock waves. The sample temperature and pressure history are determined as functions of aircraft speed and altitude. The flow environment is calculated along a streamline that begins in the undisturbed flow and passes through the shocks before entering the probe. Speeds up to Mach 3 and altitudes to 20 km are being covered by the study.

The development of the necessary reaction mechanisms and thermochemical data base to describe shock heating of the samples is in progress. While atmospheric modelers are concerned with limited temperature (217 K–250 K) and pressure (0.03–0.14 atm) ranges, the air samples could be subjected to temperatures up to 600 K and pressures 35 times higher than ambient conditions. Computational chemistry methods have been used to predict thermodynamic properties of important sample species not found in current data bases including heats of formation, specific heats, enthalpy, and entropy as functions of temperatures up to 600 K. Reaction mechanisms and thermodynamic data relevant to sample conditions are being added to the flow simulations. Conditions after normal or oblique shock are input to the model, and parametric studies of sample changes are performed as functions of aircraft speed and altitude. The species of interest in atmospheric sampling include ozone (O_3), oxides of nitrogen (NO, NO_2, NO_3, N_2O_5) and chlorine compounds (Cl, ClO, ClO_2, Cl_2O_2, $ClNO_3$). Shock heating can convert the species being measured to other compounds. For example, if nitrogen dioxide were to be sampled, its concentration might be significantly increased from the ambient amount by the following reactions that can occur after shock heating:

$$NO + O_3 \longrightarrow NO_2 + O_2$$
$$ClNO_3 \longrightarrow ClO + NO_2$$

Preliminary results show that the chemical integrity of the sample depends on the aircraft speed and the species. For example, at Mach 2, the above reactions do not begin for approximately 10 milliseconds. At Mach 3, however, the sample begins to change composition in about 1 microsecond. The amount of change that can be tolerated depends on the species being measured and the time required to hold the sample. The effects of shock heating are currently being investigated for other reactions and species. If the sample heating is too severe to permit chemical integrity, then the possibility of sampling from the cold leeward side of a flat plate inclined to the flow will be examined.

Significance of the results

Although there has been speculation about the effects of sampling from supersonic aircraft, no previous studies of this phenomenon have been made. This work combines the unique capabilities of the Computational Chemistry Branch at the Ames Research Center to predict species thermodynamic properties and reaction rates with reacting flow modeling to examine this important issue.

Keywords

Atmospheric sampling, Ozone depletion, Supersonic flight, Stratospheric chemistry

Formation of Organic Matter from Carbon Dissolved in Minerals

Investigator(s)
Narcinda Lerner, Ames Research Center,
Moffett Field, CA 94035-1000
Friedemann Freund, SETI Institute,
Ames Research Center

Before life could start on the early Earth some 3.2 billion years ago or earlier, there must have existed a large reservoir of abiotically formed organic matter. The first organisms that evolved must have used these pre-existing organic molecules to build their bodies and metabolic functions. To understand how this happened is a BIG question. Unfortunately, in spite of impressive progress in the origin of life field, it is probably fair to say that none of the numerous gas–phase, liquid–phase or gas/liquid–solid phase reactions that have been studied in depth so far have led to a breakthrough in our understanding. A major shortcoming of all prior experiments is that they tend not to produce the complex organic molecules that early life most probably needed to get started. Either nature is so complicated that we become more confused the deeper we penetrate into the question of the origin of life or we miss something fundamental.

This project takes a fresh, unconventional look at the mechanisms by which organic molecules can be made abiogenically, in particular complex organic molecules. We want to test the proposition that magmatic minerals are a medium in which precursor organic molecules are formed and are then liberated when the minerals are washed and weathered away.

Magmatic minerals are, as their name suggests, unlikely candidates to allow for the formation of delicate organic molecules. Magmatic minerals crystallize under fiery conditions from molten rocks at red hot temperatures. However, as they crystallize, they also dissolve H_2O and CO_2 in their crystal structures. As the rocks that contain these minerals are uplifted toward the surface of the Earth, they cool and decompress. Strange things happen during the cooling and decompression when the gases exsolve.

Recent studies on model systems, in particular simple MgO and CaO crystals, have demonstrated that structurally dissolved H_2O (and probably CO_2) are prone to undergo a redox conversion inside the mineral matrix forming H_2 (and reduced C) plus peroxy. This means that the original H_2O and CO_2 molecules split into a reduced half and an oxidized half. During exsolution the reduced half, H_2 and C, will be separated from the oxidized half, the peroxy which stays in the mineral matrix. As H_2 and C exsolve, they are also likely to react with each other when they arrive at major lattice defects such as dislocations and subgrain boundaries. There, they form precursor entities of the sort $(H_xC_yO_z)^{n-}$, which in turn should yield organic molecules when the minerals are weathered. Since this reaction takes place inside a two-dimensionally structured matrix, the organic molecules thus formed can be complex and can be stereochemically restrained— both apparent prerequisites of early biochemistry.

The challenge of the work undertaken in this DDF project is to prove experimentally that the proposition presented above is valid and that it leads to complex organic molecules that can be distinguished from omnipresent contamination by today's biomolecules in the environment.

A 10 kW carbon arc fusion furnace has been set up to melt simple oxides like MgO and CaO and grow large single crystals from the melt. So far we have obtained small single crystals. We are in the process of improving the technique and hope to have the crystal growth procedure under control soon so that we may use isotopically labeled D_2O and $^{13}CO_2$ for incorporating into the crystals.

We also developed, in collaboration with the Balazs Analytical Laboratories, Sunnyvale, Calif., a procedure to determine the total organic carbon (TOC) content in our crystals. According to current results, large MgO single crystals that were grown by the same technique by Spicer Ltd. in England do contain up to 55 parts per million (ppm) organic carbon. This concentration is very high and, if confirmed, would already in itself lend the strongest support to our unconventional proposition.

We have also developed and tested a new analytical technique to determine the peroxy content in our crystals and, more importantly, in natural minerals and volcanic gases. In addition, we have collected organic gases that are released during fracture of natural minerals from the upper mantle either in ultrahigh vacuum or under nitrogen + hydrogen gas in a specially designed all stainless steel and titanium "coffee grinder." In collaboration with Peter Palmer these gases have been analyzed by gas chromatography and mass spectroscopy. Very encouraging results have been obtained. A collaboration has been established

with Bernd Simoneit of Oregon State University at Corvallis to begin during FY95 an indepth study of samples that we will prepare at Ames Research Center under a variety of gases, in particular deuterated gases that can interact with the precursor organic entities.

We shall continue our work on the carbon arc fusion furnace, continue and improve the peroxy and TOC analyses, and continue our crushing and grinding experiments to collect gases from minerals. During FY95 we hope to enroll the help of Alka Gupta who, as an organic chemist, will dedicate about 50 percent of her time to developing much needed analytical procedures for the detection of complex, highly oxygenated organic molecules.

Keywords

Origin of life, Organic synthesis, Abiogenic synthesis, Minerals

Surface Shear Stress Measurement Using Liquid Crystal Polymers

Investigator(s)
B. G. McLachlan and J. H. Bell,
Ames Research Center,
Moffett Field, CA 94035-1000

Other personnel involved
M. L. Brandes and M. Gouterman,
University of Washington
Seattle, WA 98195

Objectives of the study

Assess the feasibility of using liquid crystal polymer (LCP) film coatings for surface shear stress measurement in aerodynamic testing.

Progress and results

1. Demonstrated the viability of using the birefringent response of LCP coatings as a basis for aerodynamic shear stress measurements.
2. In order to quantitatively evaluate LCP coatings, a new benchtop flow chamber apparatus was designed and fabricated to produce a known shear stress level of high accuracy and of a magnitude comparable to that found in large scale testing.
3. Because imaging apparatus noise was identified as a major problem in the measurement, a new imaging apparatus has been designed and is under fabrication to reduce noise in the measurement.
4. Liquid crystal co-polymers (LCCP) are under evaluation as a basis for shear sensitive coatings.

Significance of the results

The LCP approach does not suffer the drawbacks of the present shear stress field measurement methods (oil film interferometry and low mass liquid crystals) and has other advantages in comparison to them.

Keywords

Aeronautical sensor, Aerodynamic shear stress measurement, Liquid crystal polymer

Impacts of Automated Differentiation on Numerical Design Optimization

Investigator(s)
Hirokazu Miura, Ames Research Center,
Moffett Field, CA 94035-1000
Ilan Kroo, Stanford University,
Palo Alto, CA 94305

Other personnel involved
Steve Altus, Stanford University,
Palo Alto, CA 94305

Objectives of the study

Aircraft design is a highly complex nonhierarchical process with intricate interactions among disciplines. We are trying to find a hierarchical program architecture that is amenable to parallel computation on multiple workstations on a local network.

Progress and results

Two types of program architecture were tested and one architecture was made operational for design optimization performed on the three networked workstations at Stanford University.

Significance of the results

Collaborative design synthesis on a distributed computing facility was demonstrated to be feasible and reasonably efficient. However, the convergence characteristics are not as spectacular as expected, thus there is still more work to investigate the basic nature of the new architecture.

Publications resulting from study

Kroo, I.; Altus, S.; Braun, R.; Gage, P.; and Sobieski, I.: Multidisciplinary Optimization Methods for Aircraft Preliminary Design. AIAA-94-4325-CP, presented at 5th AIAA / NASA / USAF / ISSMO Symposium on Multidisciplinary Analysis and Optimization, Panama Beach, Fla., Sept. 7–9, 1994.

Keywords

Aircraft design, Collaborated design, Automatic differentiation

The Opacity of Water Vapor

Investigator(s)
Harry Partridge and David Schwenke,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The objective of this research is to determine accurate opacities for hot water vapor, which are required for modeling the atmospheres of oxygen-rich cool evolved stars (CES). The relatively low surface temperature of these stars results in a high concentration of molecular species in their atmospheres and the spectra of these stars are dominated by many overlapping molecular bands. Considerable effort has been devoted to constructing model atmospheres of CES, but progress is limited by the lack of accurate opacities for water vapor at stellar temperatures. The available laboratory data are insufficient to accurately specify the opacities. However, the required opacity data can be obtained by quantum mechanical calculations that solve both the electronic and the nuclear Schroedinger equations. This project involves three principal steps: 1) determination of an accurate dipole moment surface for water; 2) development of a hybrid potential energy surface for water using the accurate experimental potential near the equilibrium geometry and the ab initio results for highly distorted geometries; and 3) determination of the ro-vibrational energy levels and their intensities for all levels that are significantly populated at stellar temperatures.

Progress and results

The ab initio electronic structure calculations to determine the dipole moment and energy surfaces are nearly complete; approximately 600 geometries were needed to represent the surfaces. The computed energy surface is in excellent agreement with the experimentally derived surface up to about 20,000 cm^{-1}, which represents the energy regions for which spectroscopic data are available. At energies in the region 25,000 to 40,000 cm^{-1}, substantial errors are obtained by simply extrapolating the experimental potential.

Significance of the results

The computed energy surface has been shown to agree with the experimentally derived surface in regions where it is well defined. This gives confidence that the computed dipole and energy surface are accurate. This will permit the development of a hybrid potential energy surface that will incorporate the experimental data and extend the surface to higher energies (higher temperatures). Given an accurate potential energy and dipole moment surface, we will solve the nuclear Schroedinger equation to determine the ro-vibrational spectrum and intensities. The goal is to compute the line intensities for all the levels populated at stellar temperatures. The opacity data will be generated in a format that is consistent with the Code S opacity codes.

Keywords

Opacity, Water

An Ultralow-Temperature Thin-Film Thermometer

Investigator(s)
Pat R. Roach, Ames Research Center, Moffett Field, CA 94035-1000

Other personnel involved
Al Spivak and Mic Clark, Trans-Bay Electronics, Inc., Ames Research Center

Objectives of the study

The purpose of this project is to develop a simple, accurate thermometer that will be useful in the temperature range of 0.01–0.38 K for use with cryocoolers that are being developed to operate at 0.10 K and below. There are currently no thermometers for this range that are reliable, accurate, and simple enough for unattended operation in an orbiting telescope. We want to develop a thin-film resistance thermometer that is accurate, sensitive, and reproducible after cycling to room temperature. Because it is a resistive device, it will be very simple to measure.

The idea behind the thermometer is that certain gold-aluminum alloys have a superconducting transition temperature that depends on the ratio of the two metals. If a thin-film serpentine pattern of Au-Al alloy is created that varies in its composition from 86% Au–14% Al (which superconducts at 0.38 K) to 96% Au–4% Al (which superconducts at 0.01 K), then there will be a continuous decrease in resistance of the pattern as the temperature of the thermometer is lowered from 0.38 K to 0.01 K because more and more of the film will become superconducting.

The objectives are:

1. Design the serpentine pattern to maximize the pattern length and area of thermal contact in a small package.
2. Evaporate the gold and aluminum films in the correct composition gradient.
3. Etch the pattern in the film and diffuse the Au and Al together.
4. Evaluate the thermometer behavior (sensitivity and reproducibility) at low temperatures.
5. Develop solutions for problems that are revealed. Possible problems are sensitivity to air or moisture, sensitivity to the Earth's magnetic field, poor thermal contact, hysteresis in the superconducting transitions, and problems with electrical contacts to the thermometer.

Our initial work indicated that it was a problem to get the gold-aluminum alloy to bond to the sapphire substrate and that the attachment of leads to the film was difficult. For these reasons we consulted with a leading manufacturer of thin-film low-temperature thermometers, Lake Shore Cryotronics, Inc., in Westerville, Ohio. They agreed to fabricate the thermometers for us. They suggested using an existing pattern that they had used before, although it was much smaller than the one we had designed. This pattern is shown in figure 1.

Their experience in working with thin films of gold suggested a solution to the problem of adherence to the substrate: a very thin film of hafnium was first deposited on the substrate before the gold and aluminum. They also suggested a method for creating the gradient in the aluminum concentration. After the uniform gold layer was deposited by high-vacuum

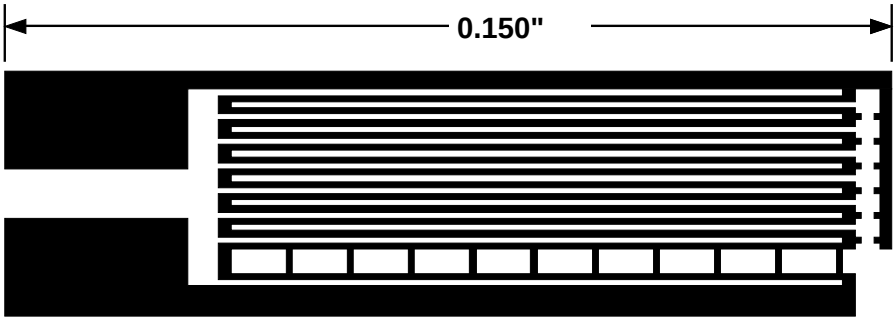


Figure 1. Thin-film resistor pattern used for superconducting thermometer.

evaporation, a special moving mask was used for the deposition of the aluminum. This mask had a triangular hole in it that passed over the substrate, as shown in figure 2. The mask allowed the continuously evaporating aluminum to reach the substrate only where there was a cut-out. At the narrow point of the triangle very little aluminum was deposited during the pass of the mask over the substrate, whereas at the broad end a much larger amount was laid down. With this geometry, each narrow line of the resistor pattern has a concentration gradient from one end to the other. After deposition, the gold and aluminum were diffused together at high temperature. Then the serpentine pattern was etched into the film and leads were attached to the large pads by thermosonic ball bonding.

Eight of these thermometers have been made and they have all been checked at room temperature, 77 K, and 4.2 K. Their resistances go from approximately 1,000 Ω at room temperature to approximately 800 Ω at 4.2 K. The lastest modifications of our low-temperature refrigerator, a He_3-He_4 dilution cooler, have almost been completed, and it will be used to test the thermometers soon.

To date we have demonstrated that thermometers of the appropriate configuration can be fabricated. These thermometers are relatively rugged and have leads on them that withstand considerable handling. The low-temperature testing to be conducted soon will answer the crucial questions about their sensitivity, reproducibility, and actual operating range of temperature.

Keywords
Resistance thermometer, Low temperature, Superconducting thin film

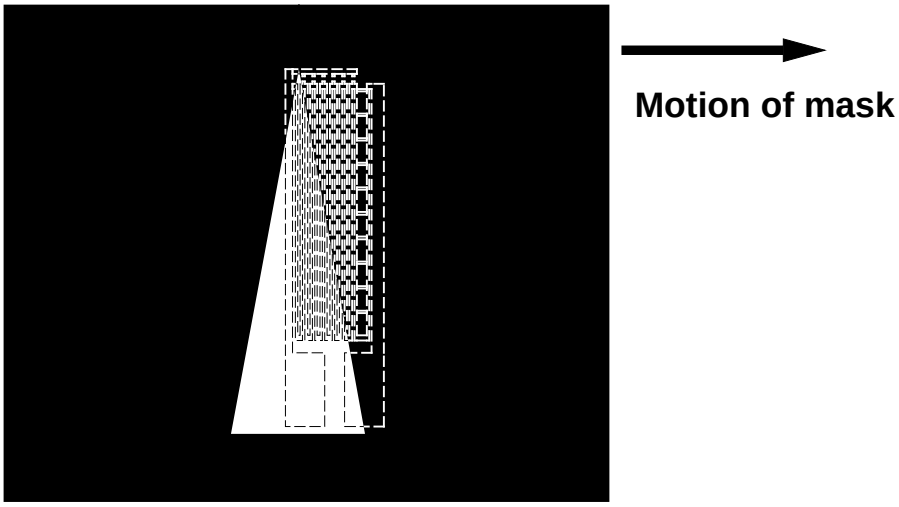


Figure 2. Mask for evaporating a gradient of aluminum onto substrate. The pattern shown is where the film will be etched after evaporation.

Deep Near-Infrared Cosmological Surveys

Investigator(s)
Thomas L. Roellig and Edwin F. Erickson,
Ames Research Center,
Moffett Field, CA 94035-1000
Jacqueline A. Davidson, SETI Institute,
Ames Research Center

Other personnel involved
Arati Chokshi, Infrared Processing and
Analysis Center and The Indian Centre for
Astrophysics, California Institute of Technology,
Pasadena, CA 91125

Objectives of the study

Imaging measurements of distant galaxies can serve as an excellent probe of the space-time curvature of the universe if galaxies are uniformly distributed throughout space on a sufficiently large scale. Therefore, measurements of distant galaxies can help answer one of the most important questions in cosmology: whether the universe is open and will continue expanding forever, or closed, in which case it will eventually stop expanding and instead collapse again in a "Big-Crunch." These measurements can also set strong constraints on the existence of the various exotic particles (such as WIMPS, MACHOS, etc.) that have been postulated to be responsible for the missing mass in the universe. Our objective is to determine the envelope of parameters within which near-infrared imaging surveys with a small dedicated space mission will have the maximum impact on cosmology studies.

Progress and results

In the first year of this study we have generated a detailed model of galaxies as they would appear in both closed and open universes. This model accurately depicts the appearance of spiral, elliptical, and irregular galaxies in the 1–10 μm wavelength range out to red shifts of 3.0. We have used this model to probe the ability of a dedicated space mission to take deep near-infrared images to get number counts of galaxies. Our preliminary findings indicate that, in order to discriminate between open and closed universes, such a mission would require: 1) good sensitivity, 2) sensitivity to wavelengths longer than 5 μm to be able to measure the red shift of galaxies with red shift z greater than ~1.5, 3) sampling at wavelengths spaced no more than 1 μm apart in order to eliminate excess noise in the total number N versus z plots, and 4) very accurate estimates of galaxy merger rates. In the coming year we will investigate the effects of source confusion, work at removing some small systematic effects in our analysis, and set stronger constraints on the missions size needed to realize the observational objectives.

Keywords

Cosmology, Near-infrared imaging, Source counts

Utility of the Experimental Electro-Optical Camera (SPEC-T) for Assessment of Insect/Drought Related Forest Mortality

Investigator(s)
Gary A. Shelton and Vincent G. Ambrosia, Ames Research Center, Moffett Field, CA 94035-1000
James McKean, U.S.D.A. Forest Service, Pleasant Hill, CA 94523

Other personnel involved
John C. Arveson, Ames Research Center
Edward A. Hildum, SVERDRUP, Ames Research Center
Jeffrey S. Myers, ATAC, Inc., Ames Research Center

Objectives of the study

Evaluate and test the application of a newly developed, high spatial resolution, electro-optical digital camera system (SPEC-T) for use in detecting insect/drought related forest mortality and other environmental assessments that require high spatial/spectral resolution data sets. Test and evaluation of system configuration and utility for inclusion of SPEC-T as part of NASA's supported suite of research and applications aircraft instruments.

Progress and results

Data collection was attempted over study sites in early June 1994, but the system was operable only for the secondary site near Lake Tahoe, Calif. Evaluation of this alternate data set was promising and changes to both the focusing and exposure timing were completed. A successful data collection mission over our primary site was completed on 25 August 1994 near McCloud, Calif. The system, through the continuing development resulting from these test flights, is operating successfully and with little downtime. Our analysis of the August data set is preliminary.

Significance of the results

The electro-optical camera has seen significant development and increased payload operations. The system, partially through the DDF support, has been developed into a fully operational NASA instrument. Because of its promotion instrument enhancements, the system is continuously in demand on ER-2 flights and it supports a wide range of research and applications missions and projects. Those projects have included the Navy Monterey Area Ship Track (MAST) experiment involving the ER-2 data collection and near-shore monitoring.

The analysis phase of the insect/drought data acquisition is currently under way with the August 1994 data sets. DDF funds from FY94 have been forwarded to FY95 to continue the applications test. The U.S.D.A. Forest Service is therefore interested in the system as a potential supplement to current aerial photography and/or unstable scanner data.

Publications resulting from study

Ambrosia, V. G.; and McKeen, J.: Utility of the Electro-Optical Camera (SPEC-T) for Assessment of Insect/Drought Related Forest Mortality. Paper presented at the Fifth Biennial Conference on Remote Sensing Applications in the Forest Service, Portland, Ore., Apr. 1994.

Keywords

Electro-optical camera, Remote sensing, Ecosystem analysis

Development of a New System for Canopy Architecture Remote Sensing

Investigator(s)
V. C. Vanderbilt, Ames Research Center,
Moffett Field, CA 94035-1000
A. W. Sarto and B. J. Van Zeghbroeck,
University of Colorado, Boulder, CO 80309

Objectives of the study

This remote sensing project has developed a new theory and measurement method for an emerging remote sensing technology—canopy architecture remote sensing—which will supplement the existing optical and microwave remote sensing technologies.

Progress and results

We have developed a new theory and a new laser based measurement method for remotely sensing canopy architecture. The theoretical development has supported development of a proof-of-concept instrument.

Theoretical development

We divided the theoretical problem of understanding and extracting the information in the laser pulse returned to a lidar located above a plant canopy:

- During the first year, we developed a stochastic process model to mathematically describe canopy architecture. We constructed state-of-the-art detectors for use in a proof-of-concept system for measuring canopy architecture.
- During the second year, we used the results of our canopy architecture model to design and assemble a proof-of-concept system.

In the stochastic architecture model, the stochastic variable is not time but rather (x,y,z) position and possibly (q,f) direction in the canopy. In the model, the canopy statistical properties are computed from the statistical properties of an ensemble of 'plots' selected from within the canopy. This model supports definition of an autocorrelation function for canopy architecture, providing a fundamental measure of canopy architectural properties. Examples in this report illustrate application of the theory to the problem of quantifying canopy architecture.

Development of a proof-of-concept instrument

Background

Recent research has demonstrated the potential of metal–semiconductor–metal (MSM) photodetectors to attain extremely short response time constants required for use in the canopy architecture measurement system. The research has shown that these extremely fast MSM photodiodes, fabricated as single detectors or as arrays of detectors, perform well in a frequency mixing mode of operation, a fact which we have exploited in the design of the canopy architecture measurement system.

Rather than acquire data at gigahertz (GHz) frequencies, the canopy architecture measurement system we are developing will sample the output of a superfast array of MSM photodetectors with GHz bandwidth, allowing data collection at a much lower frequency than the GHz regime. This sampling design takes advantage of the signal mixing capability of the MSM photodiodes and avoids the need to fabricate a GHz transmission line connection to each element of the array.

First year progress

During the first year, we designed and fabricated at the University of Colorado extremely high speed, MSM photodetectors—both single detectors and arrays of detectors—for use in the proof-of-concept lidar canopy architecture sensor. The MSM detectors, the critical component in the canopy architecture instrument, are capable of providing an output current proportional to the incident light. In a test a sample MSM detector exhibited a response time that would allow the architecture of even miniature canopies to be measured.

Second year progress

During the second year, we first assembled a proof-of-concept measurement system that allowed us to demonstrate the feasibility of the design approach. Tests showed that the nonoptimized laboratory system could resolve the distance between even closely spaced leaves—as, for example, would be found in a

plant canopy having a spatially clumped leaf distribution. Because these laboratory results were extremely encouraging, we ordered additional parts and are now reassembling the proof-of-concept system in a package more suitable for measurement of plant canopies. During the coming year, in cooperation with controlled ecological life support systems (CELSS) scientists here at Ames Research Center, we plan a series of measurements of plant canopies, grown in environment chambers, in order to better assess the advantages and limitations of the present design of our instrument as it provides canopy structural data to plant scientists.

Significance of the results

The progress and results to date are extremely encouraging. They have laid the foundation for our efforts to establish a new area of remote sensing—plant canopy structure remote sensing. Our new model for canopy architecture provides the needed theoretical basis for mathematically describing canopy structure. Essential and necessary parts of the instrument, the state-of-the-art MSM detectors, and detector arrays have been successfully fabricated. The feasibility of the instrument design has been demonstrated using a proof-of-concept, laboratory-based system. We are now assessing the advantages and limitations of the present instrument design applied to measurement of the structure of CELSS plant canopies. The progress and results to date provide an important first step in our efforts toward gaining wide scientific recognition and acceptance of our approach to canopy architecture remote sensing.

Publications resulting from study

A draft report, Stochastic Model of Plant Canopy Architecture, has been written by V. C. Vanderbilt, 1993.

Keywords

Canopy architecture, Stochastic model of canopy architecture, Measurement of canopy architecture

Technology Utilization of Adaptive Structures in Active Electronic Equipment Isolation

Investigator(s)
David F. Voracek,
Dryden Flight Research Center,
Edwards, CA 93523-0273

The research involves the investigation and design of an active isolation system for airborne electronic equipment using adaptive structure material. The main objective is to research and develop adaptive or smart structure concepts and applications for use in active vibration suppression and isolation. The specific objectives of this research are:

- to develop and augment as necessary the current analysis, structural modeling, and applications of adaptive structures in vibration isolation systems (use of the materials, power requirements, and system design are issues that must be addressed);
- to devise a process for control system design for an active vibration isolation system; next,
- to implement the process for an active plate isolation system for aircraft avionics and other sensitive electronic equipment
- to prototype the flight hardware for in-flight testing of an active vibration isolation system; and finally,
- to flight test the prototype isolation system.

The research benefits will include the utilization of new technologies of adaptive and smart structures. If a viable design can be made operational, it will result in the use of more commercially available electronic equipment, which will reduce costs of redesigning commercial equipment to military and NASA specifications; reduce structural weight of the electronic equipment; reduce the time and expense of environmental tests; prevent damage to electronic equipment during flight or the environmental test that could result in lost research data, delays in major programs, or a complete shutdown of a research effort; and finally, increase aircraft safety. Finally active isolation will be a more robust and effective isolation system than current passive methods.

During the first year the properties of piezoelectrics were analyzed and a study of the equipment and control system required to use piezoelectrics in an active damping system was completed. The results of these studies included building a damping system for a model aircraft wing that uses piezoelectric sensors and actuators. Also a demonstration of a possible active isolation system design for electronic equipment has been manufactured and is currently in testing. NASA Dryden Flight Research Center worked closely with California Polytechnic State University, San Luis Obispo, Calif., on the damping system for the model aircraft wing. Active Control Experts, a company in Cambridge, Massachusetts, who specializes in piezoelectric sensors, actuators, and motion control systems worked on the demonstration model of the active isolation system design. The future plan is to finalize a design for a flight test article, build the hardware and control system, and then flight test the isolation system.

Keywords
Active isolation, Smart structures, Piezoelectrics

Does the Collapse of Diatom Blooms Trigger Coccolithophore Blooms?

Investigator(s)
Robert Wrigley and Lynn Rothschild,
Ames Research Center,
Moffett Field, CA 94035-1000

Objectives of the study

The immediate objective is to determine if there is a causal relationship between the end of a diatom bloom and the beginning of an *Emiliania* bloom, and if so, what its chemical basis is. The ultimate objective is to predict the onset of *Emiliania* blooms to better monitor them by remote sensing. Our data may suggest ways to alter the global carbon cycle by triggering or suppressing *Emiliania* blooms.

Progress and results

Purchased equipment vital to this study: an environmental chamber in order to grow cells under simulated natural light and temperature conditions; a Coulter Counter, which allows quick and accurate cell counts; and an upgrade to a compound microscope, which allows visualization of the coccoliths on *Emiliania.*

Obtained cultures of diatoms and *Emiliania.* Some have been successfully established on the artificial seawater medium whereas others seem to grow only on enriched seawater.

Significance of the results

Many of the phytoplankton obtained do not seem to grow in the defined seawater, probably because they need trace compounds that are not being added. For this reason, it is likely that the experiments will have to be conducted in actual seawater.

Publications resulting from study

Rothschild, L. J. : CO_2 and Diatom Mats. Nature , vol. 368, 1994, p. 817.

Keywords

Coccolithophores, Plankton blooms, Carbon cycle

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1995	Technical Memorandum, Fiscal Year 1994

4. TITLE AND SUBTITLE

Director's Discretionary Fund Report for Fiscal Year 1994

5. FUNDING NUMBERS

307-51-50

6. AUTHOR(S)

Ames-Moffett and Ames-Dryden Investigators

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Ames Research Center
Moffett Field, CA 94035-1000

8. PERFORMING ORGANIZATION REPORT NUMBER

A-94135

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM-108848

11. SUPPLEMENTARY NOTES

Point of Contact: John T. Howe, Ames Research Center, MS 200-16, Moffett Field, CA 94035-1000
(415) 604-5500

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified-Unlimited
Subject Category – 99

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

This technical memorandum contains brief technical papers describing research and technology development programs sponsored by the Ames Research Center Director's Discretionary Fund during fiscal year 1994 (October 1993 through September 1994). An appendix provides administrative information for each of the sponsored research programs.

14. SUBJECT TERMS

Director's Discretionary Fund, Space science, Life science, Aeronautics, Space and terrestrial applications

15. NUMBER OF PAGES

112

16. PRICE CODE

A06

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		